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ORIGINAL ARTICLES.

I.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, F.G.S.

(*Continued from Decade VI, Vol. I, November, 1914, p. 483.*)

PLATE VI.

Membranipora subacuminata, nov. (Pl. VI, Figs. 1, 2.)

Zoarium unilaminate, always adherent.

Zoœcia separated by a distinct furrow, which passes into a deep crevice at the junction points, widely rounded below but tapering very considerably and almost to a point above, with areas of the same shape and upright rounded side walls thickening considerably below, and often developing something of an internal front wall; average length of area ·28 mm., breadth ·2 mm., but marginal zoœcia often run much larger.

Oœcia. No trace of any oœcium has been observed.

Avicularia vicarious, humble examples of the '*Lesueuri*-type', as although strictly conformable in general structure they are only a little larger than the surrounding zoœcia; the node at which the very scanty front wall of the lower part splits into two is very inconspicuous, and the internal front wall of the upper part is relatively much wider than usual in proportion to the section of the area which it encloses. (I have always felt that it would be admissible to argue, on the species standing by itself, that these cells were not avicularia but ordinary zoœcia with the addition of a wholly unroofed oœcial chamber; but I have never doubted myself that they were avicularia, and the recently discovered species which follows seems to put this beyond doubt.)

This species is only known to me from the base of the zone of *B. mucronata* at Portsdown, where it is scarce but well distributed.

Membranipora Studlandensis, nov. (Pl. VI, Figs. 3, 4.)

Zoarium unilaminate, adherent.

Zoœcia piriform in outline (there being a considerable expanse of flat front wall below the area), and separated only by sutures; areas practically circular, average diameter ·28 mm., but occasionally much larger ones occur.

Oœcia globular, of the water-bottle type, the constriction at the neck being slight but quite distinct, with a concave free edge falling somewhat back from the areal outline, small in proportion to the zoœcia and with rather vague outlines, almost invariably present in the type-specimen. Beneath them the areal margin is low and very

thin, but maintains accurately the circular areal outline. This makes it impossible to confuse the base of the damaged œcium with the internal front wall of an avicularium as the latter sets well back from the areal outline.

Avicularia vicarious, resembling very closely those of *M. subacuminata*, but a little larger in proportion to the zoœcia and with the nodal points standing out conspicuously.

I have only one specimen, from Studland, of this species; but specimens of any adherent Polyzoa are so exceedingly scarce in the Studland Chalk and the species throws such useful light on the preceding one that I have felt justified in disregarding the general objection to a species founded on a single specimen.

MEMBRANIPORA DEMISSA, nov. (Pl. VI, Fig. 5.)

Syn. *M. Britannica*, var. *demissa*, Bryd., GEOL. MAG., 1910, p. 77, Pl. VIII, Fig. 6.

I am convinced that I was wrong in ignoring the doubts I felt at the time and treating this form as a variety of *M. Britannica*. Subsequent experience shows clearly that the front wall habitually developed in *M. Britannica* solely as a platform for the œcium or avicularium of the preceding zoœcium never approaches in size or systematic nature that of *M. demissa*, while the bold sub-triangular areas of *M. demissa* are also quite distinctive. The specimen which I now figure—from Studland, of all unlikely places—is practically the only one I possess which shows clearly and perfectly the very fragile oœcia. There are six perfect examples in the Figure. They are merely gentle and vaguely outlined swellings, with free edges which are marked off by a faint constriction and coincide exactly with the normal areal outline, and they form a strong contrast to those of *M. Britannica*, which are very bold. *M. demissa* first appears in rare small forms in the base of the zone of *B. mucronata*, but is represented by normal forms as soon as the higher Chalk of the Isle of Wight and Studland is reached.

The same treatment should be accorded to the other form described at the same time as a variety (var. *præcursor*) of *M. Britannica*, and this form must stand as a new species, *M. præcursor*. It is now known to range down to the zone of *M. cor-testudinarium*, and though upwards it ranges into the zone of *B. mucronata*, it does not appear to reach the Weybourne Chalk, and as *M. Britannica* does not appear to range down into the Weybourne Chalk, they never even meet. It would be interesting to know the exact range of *Reptoflustrella Meudonensis*, D'Orb.,[1] which looks like a relation of *M. Britannica*, though clearly distinguished by its avicularia.

MEMBRANIPORA WOODWARDI, Bryd.,[2] var. PINGUESCENS, nov. (Pl. VI, Fig. 6.)

This adherent form, which I know only from Trimingham, deserves a recognition which seems properly limited to varietal. The roundness of its areas and oœcia, the slenderness and flatness of its

[1] Pal. Terr. Crét. Franç., vol. v, p. 572, pl. 731, figs. 19–21.
[2] GEOL. MAG., 1910, p. 258, Pl. XXI, Figs. 1–3.

avicularia, and its general sleekness of appearance are points which effectively distinguish it from the typical and abundant free-growing form of the zones of *A. quadratus* and *O. pilula*, but are hardly of specific value, indicating rather a stage in the development of a single persistent form. To emphasize the range of evolution in this species I have added a figure of the form of the zone of *M. cor-testudinarium*, which is practically the earliest known.

MEMBRANIPORELLA PONTIFERA, nov. (Pl. VI, Fig. 8.)

Zoarium unilaminate, adherent.

Zoœcia slightly pyriporiform; areas oval with flattened upper end, average length ·35 mm., breadth ·2 mm.; side walls broad and bearing about six pairs of stout imperforate tubercles; in three instances in the type-specimen the area is bridged between a pair of tubercles by a broad arched bar without any lateral connexion or even suggestion of it.

Oœcia only known from damaged specimens, apparently of globular type; at the point of attachment to the front wall they generally absorb part of the highest pair of tubercles.

Avicularia small, interstitial, mandibular, with a slender transverse bar occasionally preserved quite perfect.

The figured specimen is of course very imperfect, as it must be assumed that in a perfect specimen all or nearly all the pairs of tubercles would be connected by bars in every zoœcium; but it could only be by the merest chance that such a specimen would be secured, and no amount of waiting would guarantee it. The species is an obvious warning against hasty diagnosis of forms that look like spiny *Membraniporæ*; but it is probably a safe rule, as the front wall elements of *Membraniporella* were presumably always fixed, that that genus is not in question when any of the tubercles are perforate and presumably bases of movable spines.

The species occurs very rarely in the zone of *M. cor-testudinarium* in Hants and the zone of *M. cor-anguinum* at Gravesend.

MEMBRANIPORELLA OBSCURATA, nov. (Pl. VI, Figs. 9, 10.)

Zoarium adherent, almost always more or less multilaminate.

Zoœcia very small, average length ·4 mm., with heel shaped to horseshoe-shaped apertures (the outline depending a good deal on the amount of encroachment of avicularia), the lower lip of which is a straight thickened bar generally bearing a distinct median denticle; the slightly arched front wall should be pierced by four or five pairs of radiating slits, as seen in Fig. 10, but it is only rarely that this structure can be detected, although the general aspect is so emphatically Cribrilinid that I never doubted that it would prove to belong to that family.

Oœcia. No trace observed.

Avicularia small, probably mandibular, scattered in abundance along the interzoœcial furrows, which they almost wholly obscure and often fill up to above the level of the zoœcial front walls.

This species appears to be confined absolutely to the zone of *M. cor-testudinarium*, in which it is fairly common in Sussex and occurs also in Hants and Kent. Its general indistinctness is, of course,

partly due to its exceptional smallness and perhaps also in part to the relative intractability of the Chalk it inhabits, but it must also be due in part to secondary calcification. It is clearly one, and apparently the first, of the group which includes *M. castrum*,[1] Bryd., and *M. pustulosa*,[2] Bryd., and which is otherwise, except for a very brief interval at the base of the zone of *B. mucronata*, strictly unilaminate.

EXPLANATION OF PLATE VI.

(All figures magnified 12 diams.)

FIG.

1, 2. *Membranipora subacuminata*. Zone of *B. mucronata*. Portsdown.
3. *M. Studlandensis*. Zone of *B. mucronata*. Studland.
4. *M. Studlandensis*. Another part of the same specimen showing broken oœcia.
5. *M. demissa*. Zone of *B. mucronata*. Studland.
6. *M. Woodwardi*, var. *pinguescens*. Trimingham.
7. *M. Woodwardi*. Zone of *M. cor-testudinarium*. Seaford.
8. *Membraniporella pontifera*. Zone of *M. cor-anguinum*. Gravesend.
9, 10. *M. obscurata*. Zone of *M. cor-testudinarium*. Seaford.

(To be continued.)

II.—A REMARKABLE STRUCTURE IN *LOVENIA FORBESI* FROM THE MIOCENE OF AUSTRALIA.

By HERBERT L. HAWKINS, M.Sc., F.G.S., Geological Department, University College, Reading.

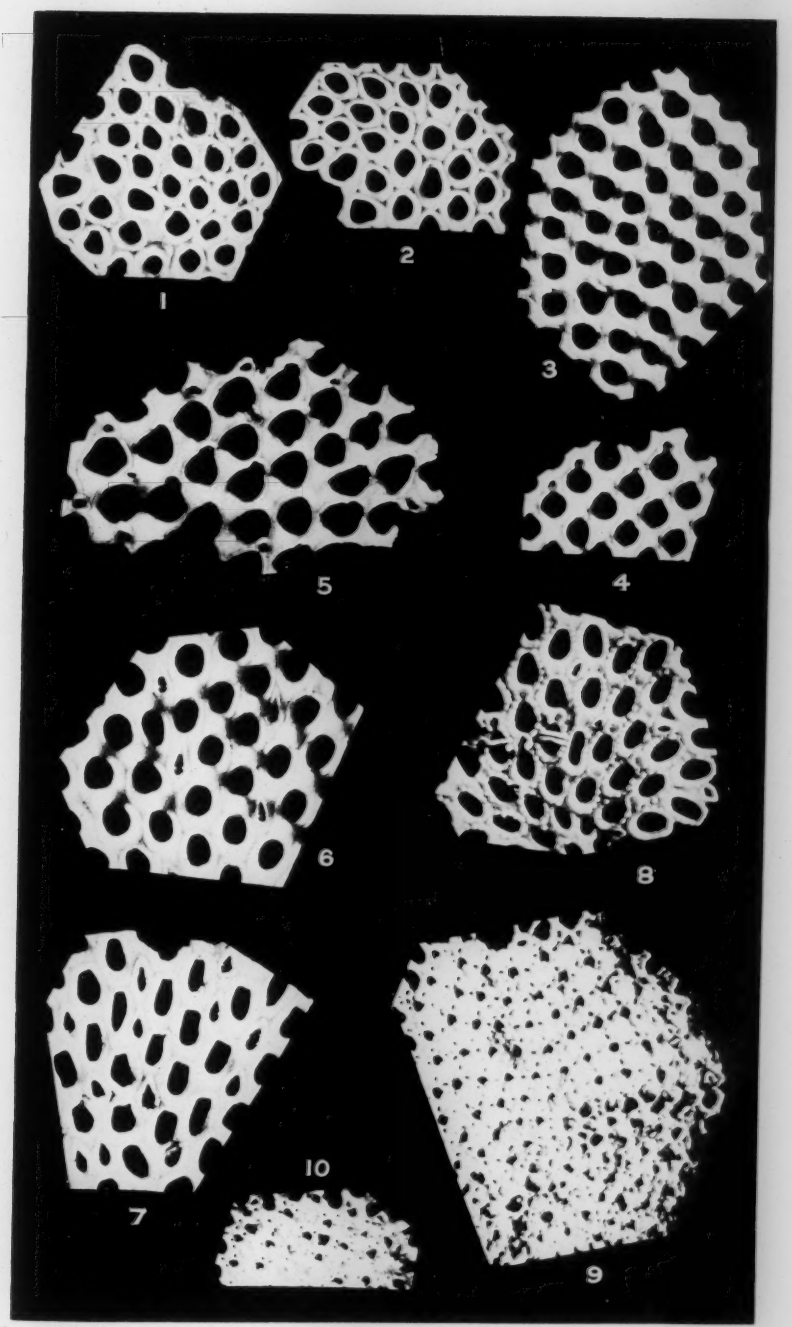
DURING the preparation and arrangement of a series of *Lovenia forbesi* from the Australian Miocene (presented to the Geological Department by Professor F. J. Cole), a peculiar interambulacral structure was displayed. Two of the specimens are severely weathered, with the result that their surfaces are smooth (except for the areolæ of the large tubercles), while the sutures are clearly outlined in dark brown across the pale background of the plates. In this way there is revealed the surprising fact that plate-crushing and resorption, of a type similar to that often found in Echinoid ambulacra, occur in four of the interambulacral areas. There is no corresponding development in the ambulacra.

As far as I am aware, this peculiar condition has not been described previously in the species under notice, nor in any other Euechinoid, whether Regular or Irregular. Apart from its intrinsic interest, this apparently unique development throws much light upon the mechanism whereby the more usual ambulacral plate-crushing is produced. Hence a brief description of the specimens seems desirable; and the description is followed by a discussion of the problem as solved by this new evidence.

The following description is based solely on the two weathered specimens referred to above. They are registered in the Palæontological Collection of University College, Reading, under the numbers 546 A and B. Their dimensions (in millimetres) are as follows:—

	Ant.-Post. Diam.	Transverse Diam.	Height.
A	21·1	20·8	12·2
B	23·0	24·0	11·2

[1] GEOL. MAG., 1909, p. 398, Pl. XXII, Figs. 4, 5.
[2] GEOL. MAG., 1910, p. 483, Pl. XXXVI, Fig. 9.



R. M. Brydone phot. *Bemrose & Sons Ltd., Collo.*

Chalk Polyzoa.

It will be noticed that A is of a slightly different form from B, being smaller, but of greater proportional length and height. Specimen B is, in fact, rather broader and flatter than is usual for the species. On the evidence of size and tuberculation, it must be inferred that A (Text-fig. 1) is a somewhat younger individual than B (Text-fig. 2), although both specimens possess approximately the same number of plates in their tests. In both examples the ambital angle is very acute, and the adoral surface almost flat.

In each of the four paired interambulacra (areas 1, 2, 3, and 4),[1] the adoral surface is entirely occupied by three plates—the unpaired plate at the peristome border, and two large multitubercular plates which make a kind of plastron. Of these large paired plates, those in columns 1*a* and 4*b* are crossed by a faint curved suture, seeming to indicate that they are of dual origin. Lovén (*Études*) has inferred that one or both of these plates are often double in Spatangids, but seems not to have detected a suture in them. There is the appearance of a similar suture across the corresponding plates in columns 2*a* and 3*b* in specimen B, but as this occurs in that individual only it requires confirmation, and is ignored in the numbering of the plates in the succeeding description and figures.

In column 1*a* (Text-fig. 1) the plate next above the ambitus (plate 4) is narrow but complete. In column 1*b* there are two imperfect, lath-like plates intervening between the large 'plastronal' plate (2) and the first tubercle-bearing plate of the adapical surface (5). Both of these imperfect plates take part in the interradial suture, but taper away towards the adradial suture, the adorally situated one being the shorter. As a result, plate 5 is in contact with plate 2 at the margin of ambulacrum II. In specimen B (Text-fig. 2) the condition in this column is precisely similar, but plate 3 is represented by a minute fragment extending for only a millimetre away from the interradial suture.

In column 2*a*, in specimen A (Text-fig. 1), plate 3 is complete, but tapers towards the ambulacrum, and is reduced to a very narrow strip at the adradial suture. In specimen B (Text-fig. 2) the corresponding plate is imperfect, disappearing at a distance of about two millimetres from the ambulacral margin. In column 2*b* plate 3 is complete, its height being about half that of the succeeding plates in specimen A, and about a quarter that amount in specimen B.

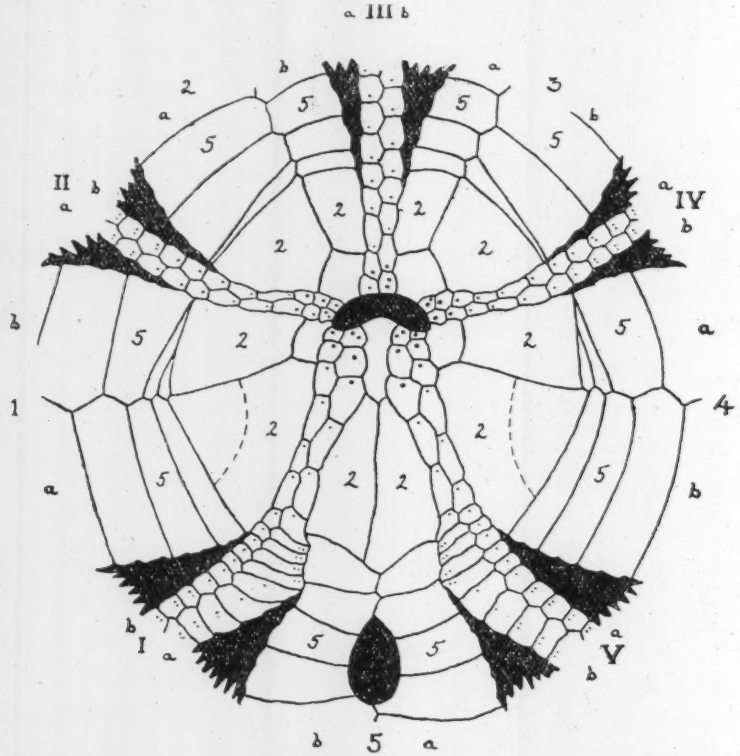
On the other side of the test precisely symmetrical and similar conditions obtain. In area 5 there is nothing comparable in degree with this compression and reduction of the plates.

From the foregoing description, and particularly from the figures, it will be seen that there is developed in the interambulacra of *Lovenia forbesi* a structure closely analogous to plate-crushing as found in the ambulacra of most Regular and many Irregular Echinoids. The only difference in character is that, whereas in ambulacral crushing the plates are usually detached from the perradial suture, here they survive at the interradial suture and fail to reach the adradial.

The plate-crushing, in so far as it produces plates homologous with demi-plates, is restricted to the two sets of interambulacral columns

[1] Lovén's notation is used throughout.

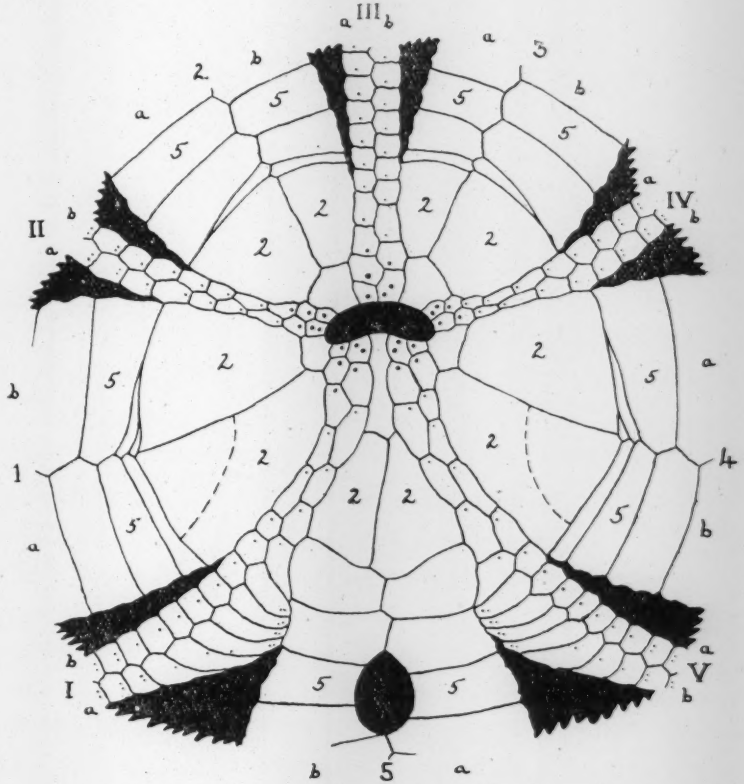
bordering upon ambulacra II and IV. This in itself may be regarded as a piece of confirmatory evidence for the association with an ambulacrum of the contiguous columns of the interambulacra, as urged by Jackson (Phylogeny). The crushing occurs, to some degree, in all four of the lateral interambulacra, and even in area 5 an appreciable reduction in the height of the plates can be detected. It affects most seriously those plates that are next above the enlarged subambital plates; and is most intense in specimen B, the older of the two. In



TEXT-FIG. 1.—Plan of the adoral and part of the adapical surfaces of specimen A of *Lovenia forbesi*. × about 2½. The lettering and numbering of areas and plates is in accordance with the method employed in Lovén's *Etudes sur les Echinoidées*. The ambitus is approximately coincident with the outer margins of the plates numbered 2. All ornament is omitted.

such specialized forms as *Lovenia*, these plates (Nos. 2 or 2 + 3), together with the primordial unpaired plate, become set apart early in ontogeny for the purpose of building a strong, flat adoral surface. There is practically no resorption of plates at the peristome; and, indeed, one might even regard the great increase in size of the adorally situated plates as constituting a "negative resorption", and possibly exerting pressure upwards.

With these large plates stereotyped and immovable, a bar to downward movement on the part of the later formed plates is developed at or near the ambitus. It appears that in *Lovenia* there is no interruption in the production of new coronal plates from the oculars (at least during a large portion of the growth period of the individual), so that the lower (older) members of each column become jammed against the adapical margins of the large plates. This assumption



TEXT-FIG. 2.—Specimen B of *Lovenia forbesi* for comparison with Fig. 1. It will be noticed that the two figures are identical except in proportions and the degree of reduction of the interambulacral plates at the ambitus.

receives strong support from the fact that in this species the greatest degree of compression of the plates occurs in the neighbourhood of areas II and IV. The actual distance (measured on the curve) between the ocular plates and the adapical margins of the large adoral plates is less along those two areas than in any other part of the test, while the number of plates in each interambulacral column is the same over the whole test. Conversely, the distance from

oculars I and V to the ambitus in area 5 is greater than the corresponding measure in any other area, and here we find but a bare indication of compression in a small reduction in the height of a few plates. A table of these measurements in the two specimens described will emphasize this point.

Number of plates in each iamb. column, 13. Distance (in mm.) from edge of ocular plates to ambitus—

	Radius II.	Interradius 1.	Interradius 5.
A . .	15·9	16·2	19·8
B . .	16·0	16·2	19·0

Average height (in mm.) of one iamb. plate in these positions—

A . .	1·223 C	1·246 C	1·523
B . .	1·231 C	1·246 C	1·461

(C indicates development of plate-crushing.)

In specimen B, where the distances are relatively shorter, but the normal plates actually larger, than in specimen A, the degree of plate compression is greater. In view of these conditions, it seems impossible to resist the conclusion that simple mechanical pressure has been the prime cause of this unusual development. The growth of tubercles (to which Lambert would ascribe much influence in ambulacral plate-crushing) can have no effect in this case, for the scattered tubercles, though large for a Spatangid, are far removed from the margins of the plates and have ample room for extension.

In comparing the development of plate-crushing in this aberrant case with the similar structures in the ambulacra of many other Echinoids, the place at which the reduced plates occur becomes an important feature. It is demonstrably at the line of junction between the unchangeable and immovable adoral plates and the less specialized movable plates higher in the column; that is, the latter plates are crushed against the barrier.

In the case of the ambulacra (and interambulacra) of the Cidaroids there is nowhere any hindrance to the progress of the plates from apex to peristome, and no plate-crushing appears. In the other Regular Echinoids, and in the Holectypoida, the major part of the perignathic girdle is established on the ambulacral plates next to the peristome, and must, to exercise its function, remain there constantly and unchanged. At once plate-crushing appears (in the ambulacra), at the peristome margin first, extending farther up the area as specialization progresses. In *Echinocardium cordatum*, as I have shown recently, an abnormal rate of plate-growth occurs in ambulacrum III; but those plates of the area that are on or below the ambitus have already taken on the large, immobile character of the plates of a Spatangid adoral surface. The new plates thus crush against a barrier situated on the adapical surface, and the compound plates are restricted to the 'petaloid' region. In the closed petals of *Clypeaster*, *Echinarachnius*, and *Laganum*, a similar block occurs at the outer limit of the petal, and crushed plates make their appearance within the petals of fully-grown specimens.

The case of *Lovenia* under notice is a further, and even more obvious, illustration of the theory of plate-crushing in Echinoids

that I have urged repeatedly; and the theory may be restated by way of a summary of the preceding paper.

In *Lovenia forbesi* (or any other Echinoid), persistent development of new plates from the ocular margin causes a downward (orad) gliding of the columns. If no structure is developed to interfere with this procession, the older plates become gradually resorbed at the peristome margin, or all gradually and uniformly decrease in size as they increase in numbers. If, however, some special character is assumed by a series of plates in a column (whether ambulacral or *interambulacral*), and this character, for reasons of function, must be maintained in a definite position in the test (e.g. the large adoral plates of the interambulacra in *Lovenia* or the ambulacral processes of the perignathic girdle in a Diademoid), the oncoming plates of the column become congested against the barrier thus formed. Under such circumstances the plates become lessened in height and restricted in width, forming demi-plates, and often coalescing to form compound plates. Plate-crushing is first developed, both ontogenetically and phylogenetically, at the line of contact between the moving column and the barrier.

The resulting structure may be adapted subsequently for special functions (e.g. phyllodes, 'prehensile' petals, or consolidation of the test fabric), but in its origin it is purely a mechanical outcome of the growth of the Echinoid test.

III.—The Application of Petrological and Quantitative Methods to Stratigraphy.

By P. G. H. Boswell, A.R.C.Sc., D.I.C., F.G.S., Imperial College, London, S.W.

I. Introduction.

On account of the aid it has given, palæontology has been termed the handmaiden of stratigraphy, but up to the present time petrology has not been called upon, so far as it might have been, to fulfil its appropriate duty towards the elucidation of the problems of stratigraphical geology and palæogeography.

The lithology of sediments has been studied very largely in the field, but is still in its qualitative stage. Systematic quantitative work has hardly been attempted. Used in conjunction with palæontology the broad study has proved of great value in determining facies, and in yielding clues to the disposition of land and water and their relative changes in past geological times. The fragments contained in the coarser rocks, such as breccias, conglomerates, greywackes, grits, etc., have been used to some extent petrologically as giving an indication of direction and distance of source, but the finer detrital minerals of sands, clays, limestones, marls, etc., have not yet been adequately studied with the same view. Our ultimate aim must be the knowledge of the exact mineral composition of every sedimentary rock in the geological column. In such a way only can the economic resources of our sediments become familiar, the exact conditions of deposit known, and the lesser features of palæogeography realized.

II. Petrological Methods.

The usual petrological methods of treating sediments by panning, and the use of heavy liquids, divide samples into two important and convenient crops of densities respectively above and below a mean of about 2·8. Of the liquids in common use, bromoform, when it can be obtained, appears to be most convenient. Operations with it are clean, and, what is of great importance when hundreds of samples are being examined, very rapid, the time taken in washing with benzene, and drying, being a minimum. Its mobility is a valuable asset, but has given rise to the objection that separations are rendered less complete on account of convection currents which are set up in it by slight differences in temperature. If necessary, care can be taken to avoid these, and in the writer's experience separation is quite as good, if not better, than with the more viscous aqueous heavy solutions, where the process takes longer and the grains move less freely. The only real objection to the use of bromoform is its loss by evaporation during separation, and while the washings (in benzene) are being concentrated. Theoretically, bromoform may be used over and over again without end, but practically there is a slow and steady loss. This may be obviated to some extent by the use of separating funnels stoppered at the top, but they are usually too small to accommodate a sufficiently large quantity of sediment, the sand, etc., tends to hang round the sides, and the subsequent washing is often troublesome. An ordinary funnel fitted with a glass stopper or a rubber tube and clip leaves little to be desired; but with bromoform a large surface of liquid is exposed to evaporation. The funnel may therefore be covered by a clock glass. Mercury potassium iodide is the most suitable of aqueous solutions, crystallizing out less rapidly and being less viscous than Klein's solution (cadmium boro-tungstate). It is very poisonous and has a corrosive action upon the skin, but these objections are not serious with clean working, for the liquid need not be touched. It should, however, be kept from air, and in contact with a little mercury. While not as convenient as bromoform, for it is less mobile, and necessitates washing with water, and consequent loss of time in washing and drying, it is the best substitute when that liquid is procurable with difficulty (as in 1914–15). It may be quickly prepared in the laboratory from mercuric and potassium iodides, and, like other aqueous solutions, may be used and recovered repeatedly without appreciable loss. For the further separation of the heavy crop (> 2·8) methylene iodide, of density about 3·33, is very convenient. The sediment is washed with benzene and the separation is therefore rapid. Its expense is an objection, but small quantities only need be employed for the (usually small) heavy crops.

The portion of density > 2·8 contains the heavy detrital minerals which are of greatest interest, beauty, and value from a stratigraphical point of view. Further separations may be made from this crop by electromagnetic and electrostatic methods, by the use of heavier liquids, and by hand-picking.

Apart from the included rock-fragments and compound grains, sediments exhibit considerable variation in petrology. Most of the

constituent minerals are allogenic. In the authigenic group occur glauconite, hæmatite, limonite, marcasite, opal, chalcedony, and other forms of secondary silica, calcite, dolomite, gypsum, barytes, etc. The cementing materials of rocks come under this head, as do also those minerals such as limonite, anatase, leucoxene, secondary silica, micaceous aggregates, etc., when they result from the decomposition in situ of other minerals. It is not certain to what extent these secondary minerals are also detrital, for they may have been themselves derived as a result of previous decomposition of rocks. Anatase has been frequently observed growing upon, and at the expense of, ilmenite and leucoxene.[1] The opinion has been expressed that the tabular form is probably always authigenic, but that the pyramidal form may be allogenic. Among the few deposits known to the writer in which anatase is really plentiful in fairly large crystals (grains ·3 mm. diameter) is the Pliocene (?) sand of St. Keverne, near the Lizard, Cornwall. The sand is full of ilmenite (decomposing to leucoxene) derived from the Lizard gabbro, and there is little doubt that the blue tabular anatase is a secondary product from ilmenite. In the Yeovil sands (Inferior Oolite) abundant yellow tablets of anatase accompany the yellow and red rutile which makes up a large part of the non-magnetic residue. Koenigsberger describes rutile pseudomorphs after anatase in the Eastern Aar mass,[2] and the unexplained abundance of rutile in many sediments indicates that much work remains to be done upon these isomers.

Glauconite may be detrital in certain cases. Dr. A. Morley Davies holds the view, with which the writer agrees, that the glauconite of some of the Mesozoic and Cainozoic deposits was derived from older beds and was not formed at the same time as the sediment. In that case redeposition probably took place under similar (i.e. reducing) conditions to those of its formation. Certainly much of the glauconite of deposits of all ages from Cambrian to Pliocene has no suggestion of foraminiferal character about the grains.

Side by side with the mineral analyses of the deposits, mechanical analyses, obtained by elutriation, should also be made. A good classification is that suggested by Mr. T. Crook: gravel 10 to 1 mm., sand 1 to ·1 mm., silt (or very fine sand) ·1 to ·01 mm., and mud less than ·01 mm. diameter. The material is, for practical purposes, sifted to 1 mm., and the mud or true clay portion estimated by difference in the elutriation with the form of apparatus he recommends.[3] If necessary, intermediate grades can be estimated and inserted later in the tables, which are not invalidated if sufficient grades had not been estimated previously. In sands (e.g. for glass-making, etc.), it is often desirable to know the percentage weights of the portions of diameter > ·5 mm. and < 1 mm. (coarse sand), > ·25 mm. and < ·5 mm. (medium sand), and > ·1 mm. and < ·25 mm. (fine sand); these can be

[1] J. B. Scrivenor, *Min. Mag.*, vol. xiii, p. 348, 1903; H. H. Thomas, Q.J.G.S., vol. lxv, p. 232, 1909; W. R. Smellie, Trans. Geol. Soc. Glasgow, vol. xiv, p. 267, 1911–12.

[2] *Economic Geology*, vol. vii, p. 697, etc., 1912.

[3] Hatch & Rastall, *Sedimentary Rocks* (London, 1913); Appendix by T. Crook, p. 350.

obtained, if required, by treatment with circular-holed sieves, but separation below ·5 mm. by sifting is hardly satisfactory.

A more detailed classification, such as the following, has then been found useful, and may be carried out with adaptations of the Schoene apparatus.

	Diameter in mm.	
Fine gravel	> 1	
Coarse sand	> ·5 and < 1	Sand grade.
Medium sand	> ·25 and < ·5	
Fine sand	> ·1 and < ·25	
Superfine sand (or coarse silt)	> ·05 and < ·1	Silt grade.
Fine silt	> ·01 and < ·05	
Clay	< ·01	Mud grade.

The mud grade may be divided, if desired, into portions of diameter greater and less than ·005 mm.

In sediments the portion of diameter between 1 mm. and ·01 mm. is found to be most amenable to treatment for heavy residues; that over 1 mm. diameter frequently contains compound grains, and consists of the lighter minerals, while that below ·01 mm. diameter, being a mud grade, tends to clog the heavy liquids during separation. During deposition (as during elutriation—the reverse process) the final velocities attained by small grains are dependent upon their surface areas (and therefore their diameters) and shape, rather than upon their densities. Nevertheless, as a result of greater density, it is found that the heavy detrital grains in any sediment often have an average diameter less than that of the lighter constituents. Minerals like mica, which have an excellent cleavage and therefore tend to occur in thin plates with a large flat surface, settle down slowly, and have, in spite of their greater density, a greater diameter than that of the accompanying quartz and felspar. Probably a constant ratio exists between the surface area (and also volume, for the thickness probably varies with the diameter) and that of the other grains, both of light and heavy minerals. As a result of measurement of material from various British sedimentary rocks, it is concluded that the volume of each muscovite grain is usually rather less than that of the average grain of quartz and felspar (perhaps about 80 per cent), but that the diameter of the flakes varies from two to four times that of the other heavy minerals. (The thickness of the mica flakes has been measured by focussing methods and birefringence.) The following are a few actual examples, selected from a large number:—

	Diameter in mm.	
	Muscovite.	Other heavy detrital minerals.
Bunter pebble-bed, Devon (Dr. H. H. Thomas)	·5	·2 to ·3
Yeovil Sands	·25	·06
Lower Greensand, Hunstanton	·6	·25
Thanet Beds, Bramford	·15	·04
London Clay, Holbrook	·2	·08
Claygate Beds	·15	·05
Boxstones (Crag)	·5 to ·6	·2
Lenham Beds	·4	·2

Elutriation methods depend upon the final velocities of subsidence

of quartz.[1] It is clear that each grade obtained by elutriation will contain a proportion of heavy grains which from their diameter ought to belong to a smaller grade. If the percentage of material greater than 2·8 in density were a considerable one, the method of grading would be vitiated. Apart from the occasional cases where quantities of such authigenic minerals as limonite, pyrite, and pyrrhotite, etc., are introduced (and these may be extracted early in the operations), the heavy crop reaches only 4 per cent by weight in special cases. The average found by the writer after numerous separations of rocks of all ages is about ·6 per cent. It is often, especially in coarser sands and sandstones, much less. Fine sands consisting largely of grains ·2 to ·05 mm. diameter, such as many of the samples of Bagshot Sands, appear to yield the largest residue (up to 4 per cent).[2] The earliest systematic work in this country on heavy detrital minerals appears to have been carried out by Allan Dick, and he was fortunate in choosing for his work Bagshot Sand from Hampstead Heath, which yields a large crop. Sands of diameter 2 to ·5 mm. (e.g. Red Crag, etc.) yield a much smaller proportion of heavy minerals.

III. The Possibilities and Limitations of the Methods.

A knowledge of the mechanical analyses of all the British incoherent sediments is economically valuable as well as of considerable geological importance. Our resources are not at present accurately known, but soil-analysts, authorities on water-supply and filtration, brick and pottery manufacturers, glass manufacturers, and workers in various branches of the engineering trades, particularly in the foundries, agree upon the importance of the data. From the purely geological point of view, many interesting deductions can be made regarding conditions of deposit, velocity of rivers and currents, and direction of drainage. We need, however, much more experimental work like that inaugurated in this country by Forbes, Sorby, and others, and carried on abroad, particularly in Germany and the United States,[3] in properly equipped laboratories. The experimental work is largely synthetic, and seeks to build up deposits under certain known conditions; the corresponding analytical work upon geological deposits has rather tended to lag behind the synthetic—a result not expected in petrology. When sufficient data have accumulated it should be possible to devise schemes for graphical representation of sedimentary rocks, similar to those in use for igneous rocks. Diagrams might be used upon maps, and being placed at certain points over an outcrop, yield at a glance information as to heteropic or isopic formations, lithological changes, presence of shore-lines, etc.

But not only should deposits actually mapped at the surface be so treated. Specimens from wells, water- and trial-borings should be carefully preserved and subjected to analysis. It is a matter of

[1] R. H. Richards, *Ore-Dressing*, 1906, tables in Appendix.

[2] Exclusive of such local sands, etc., such as those bordering the granite masses of Devon and Cornwall. These sands may be full of tourmaline, etc.

[3] See, for example, the recently published Professional Paper 86, U.S.G.S., "The Transportation of Débris by Running Water" (G. K. Gilbert).

great regret that tens of thousands of borings should have been made and so little of the material met with preserved. For mechanical analyses only 10 to 20 grams of the deposit are required, and for mineral analyses about a kilogram. It is to be hoped that this work will be developed in future. The drawing of sub-formational contour-lines has already proved of great value in water-supply questions, and in work upon concealed coalfields.[1] Combined with the isopachytes (lines joining points of equal thickness[2]) of superimposed beds, these contour-lines yield valuable information as to the date and trend of folds and faults and the extension of deposits underground. But it is also necessary to know the lithological variations of the buried strata, and if contour-like grade-lines are also to be plotted upon maps, and compared with isopachytes and sub-formational contours, our basis of work on underground deposits must be quantitative. If from the graphical representation of sediments (preferably from curves) we can devise a scheme which represents by a number the average mechanical composition of a rock, we shall, by plotting these numbers referring to 'grades' upon a map, and drawing 'contour-lines', possess a valuable method of indication, not only of thicknesses of beds (by isopachytes), and of the form of the surfaces of concealed beds (by contours referred to Ordnance datum), but also of changes in lithology, the proximity of axes of unrest, etc., in rocks now buried deeply. Such information cannot fail to be of considerable economical value, and its academic interest is as great. In questions of water-supply much time and money will be saved if the thicknesses and exact mechanical composition (and therefore the permeability and filtering value) of the various members of the overburden with respect to the water-bearing stratum are known.[3]

Not only the mechanical composition, but the mineral constitution also, of each bed occurring in a boring, should be worked out. Evidence of unconformity between rock-series is thus accentuated and may be of value where fossil evidence is lacking or the relations of the beds obscure in the small core of the boring. It may be serviceable in certain areas, for example, to regard the change of mineral composition which usually exists, as the dividing line between the Permian and Triassic systems. The proximity of masses of crystalline rocks, of igneous bosses, etc., or even areas of ancient sediments forming old land-areas, may be revealed from borings as a result of the study of detrital minerals of the sediments bordering such land-areas. Additional information may be gained regarding

[1] Since the above was written Professor W. G. Fearnsides has read a paper before the British Association upon the Underground Contours of the Barnsley Seam (GEOL. MAG., October, 1915, p. 465). See also "The Use of Thickness Contours in the Valuation of Lenticular Coal Beds" (G. S. Rogers and C. E. Lesher): *Econ. Geology*, vol. ix, p. 707, 1914.

[2] Professor E. Hull used the term isodiametric (or isometric) lines, as those joining points of equal thickness of a formation *before denudation* had acted upon it. See Q.J.G.S., vol. xviii, p. 127, 1862.

[3] C. S. Slichter, "Motions of Underground Water": Water Supply and Irrigation Papers, No. 62, U.S.G.S. Hazen's 'Uniformity Coefficient' obtained by sifting is not satisfactory, and is applicable only to coarse deposits.

the position and extent of old shore-lines, and in the development of concealed coalfields, especially on outer ground where borings are as yet scarce, indications of the possible projection of pre-Carboniferous rock masses through the workable measures must be of great value. The information obtained by a petrological study of the sediments will thus be combined with that resulting from work on the mechanical composition, and with the analysis of records of borings and their cartographical expression in the form of isopachyte systems and sub-surface contours. If the results obtained actually fall short of the above ideal, the method will still be justified. A few years ago Professor W. W. Watts wrote in his suggestive Presidential Address to the Geological Society (1911): "In order to obtain what Dr. Marr has called the 'geogram' of a formation in its greatest perfection, we require to know the entire extent of its variations, not only along its outcrop, but in that part which is hidden from sight." The whole of the section ought to be quoted, if space permitted, in this connexion. The methods of work detailed above help considerably towards the perfect conception of the 'geogram' of a formation.

(To be continued.)

IV.—The Fluvio-glacial Gravels of the Thames Valley.

By R. M. Deeley, M.Inst.C.E., F.G.S.

(Concluded from the February Number, p. 64.)

At about 55 miles we reach the Hendon Lobe fan. At Dollis Hill the base of the fluvio-glacial beds lies at a height of about 200 feet, whilst their upper limit at Hendon is about 280 feet. On Finchley Hill to the north-east the Boulder-clay lies between the levels of 240 and 340 feet. This was a small lobe, and the fluvio-glacial fan may have sloped rapidly towards the fluvio-glacial gravels of the main stream. On the section, Fig. 2, the heights are shown without correction for slope towards the River Thames.

Where the Lea and Roding Valleys join the Thames Valley, and to the east as far as Hornchurch, the ice reached the fluvio-glacial gravels of the Thames. West of Woodford, at 43 miles, gravel caps the watershed between the Lea and Roding. Here the height of the deposit varies from 200 to 210 feet.

That the Boulder-clay should occur here as low as 80 feet above O.D. is very interesting, for it shows that, as at St. Albans, the fluvio-glacial gravels must have been piled against the ice face and buried its end in places. Indeed, as the lower Thames is reached the evidence favours the assumption that in pre-Chalky Boulder-clay time the valley was perhaps within about 80 feet of its present depth, and was subsequently filled with a deep mass of fluvio-glacial gravel, a view, as previously stated, held by Pocock.

At Dartford Heath, 22 miles, the gravel is from 90 to 140 feet above O.D. The upper portion of this deposit looks like a schotter formed by braided streams; but the lower portion is a clean current-bedded gravel and sand, such as an ordinary river might form.

The fossiliferous gravel at Greenhithe and Swanscombe, like the Dartford Heath deposit, lies within the upper and lower limits of

the fluvio-glacial gravels; but the exact relationship of the deposits to the fluvio-glacial gravels is uncertain. It is about 28 miles from the eastern edge of the Map, Pl. IV, Fig. 1.

The gravel at High Halston, 18 miles, is a deposit which is from 100 to 200 feet high, and may belong to this series of gravels. The highest outlier at the Telegraph Station, which is still more elevated, cannot belong to the series of gravels we are considering.

Leigh, at 15 miles, shows gravel from about 150 to 160 feet above O.D., whilst the Southend gravel is from 100 to 160 feet. From the neighbourhood of Southend the gravels run in the direction of Sales Point at the mouth of the Blackwater River. In this stretch the gravel of the main stream seems to have been joined by a fluvio-glacial fan coming from the direction of Billericay, where it is from 220 to 240 feet above O.D. Its distance from the fluvio-glacial gravel of the old Thames is about 16 miles, and allowing 5 feet per mile fall we get 140 to 160 feet as the height of the gravel of the main stream.

Southminster stands on an outlier of gravel which varies from 50 to 80 feet above O.D., and this place is opposite the point where the centre line of the old Thames Valley reaches the east side of the Map, Pl. IV, Fig. 1.

All the gravels of the Tilehurst Terrace do not contain erratics derived from the glacial drifts. On the south side of the River Thames Bunter pebbles are absent, except towards the east. Portions of the gravel to the south and west were formed by the local drainage, whereas the portions to the north side of the river were largely formed by the drainage from the ice margin, the deposit becoming a more and more mixed one as it is followed to the east.

The slope of the Tilehurst Terrace deposits from the Goring Gap to the east does not appear to have been by any means a regular one; but whether the irregularity is wholly due to the varying amount of water and sediment coming down from the various ice lobes or to the subsequent warping of the district is not clear. Perhaps the debris was poured into the Thames Valley by the St. Albans Ice Lobe in such quantities that it collected here in unusual thickness in the neighbourhood of the confluence of the Colne and Thames.

At Southend the High-level Terrace Gravels wrap the slopes in a very peculiar manner. Indeed, it would appear that the present estuarine portion of the Thames Valley in pre-Chalky Boulder-clay time continued to slope to lower levels in a north-easterly direction, and that in Chalky Boulder-clay time the valley was deeply filled with fluvio-glacial gravels which have since been re-excavated, leaving traces of the High-level Gravel Terrace deposits at all heights from sea-level up to 130 feet or more.

This filling up of the valley with glacial detritus in its lower reaches may have been due to the great quantities of material thrown into the valley by the Lea Valley Lobe and the ice lobes which debouched into the valley from the rivers of Suffolk and Essex.

During the time the Chalky Boulder-clay was being laid down the Tertiary and Cretaceous rocks extended some distance in a north-easterly direction into the North Sea, being probably continuous with those of France. Since this time subaerial denudation and coast

erosion have removed this easterly watershed of the Thames and given it its present direction of outlet to the sea. Probably the initiation of the Straits of Dover dates from the advent of the first ice-sheet which crossed the North Sea to Britain, and if the Straits existed in Chalky Boulder-clay time they were probably very narrow. Indeed, the reason why the early ice-sheets of the Pleistocene period were able to cross the North Sea was the absence there of the volumes of warm water which now pass from the south through the Straits. The erratics in the raised beach of the south coast of England probably reached their present positions at a later period; for there is much evidence which favours the view that the last cold period occurred long after the Tilehurst Terrace Gravels were laid down.

It may be that the Tilehurst fluvio-glacial gravels did not at any one time quite fill the valley between the heights shown by the line B B and C C, Fig. 2; but rather that terraces of very considerable thickness were formed between these limits, for the grading and aggrading of the valley varied in accordance with the varying quantities of material thrown into it from time to time by the glacier streams.

Some of the gravels which stand at a higher level than those of the High Terrace remain to be noticed. Monckton [1] describes some gravels which rest on the Ashley and Bowsey Hills. He considers that some of the pebbles found in them point to a glacial origin. Mr. White found a pebble of grey chert with casts of detached joints of crinoids at Bowsey Hill and another of similar character at Ashley Hill. Both the black and grey cherts found may well have been derived from the Carboniferous Series to the north. These gravels also contain a great abundance of white quartz pebbles. On the north side of the Thames, opposite the Bowsey and Ashley Hills, there are also gravels at a similar height, and as shown on the Map, Fig. 1, higher-level gravels run along the south-eastern slopes of the Chiltern Hills, above the fluvio-glacial deposits of the St. Albans Ice Lobe. They also form a well-marked terrace resting on a platform about 400 feet high in the Kennet Valley and on the high land to the north-west of Bagshot. Here, however, they do not contain Northern Drift. Their extent and boundaries are very uncertain and the method of their formation is obscure. The Bowsey and Ashley Hill gravels are shown thus + in the diagram, Fig. 2. They seem to be much too high to have been formed when the St. Albans Ice Lobe was in existence. Some of the plateau gravels lower down the Thames may also be of the age of the Higher Terrace Gravels.

A possible explanation of the existence of such high-level gravels containing Northern Drift erratics may be as follows The position of the Thames Basin is a very interesting one from the point of view of stratigraphical glacialogy; for its southern, central, south-western, and western portions were outside the area occupied by the ice-sheet which advanced to some extent over the northern and north-eastern watershed; and owing to its position on the edge of the ice-sheet, it felt the full effect of any variations in the position of the ice margin.

[1] Q.J.G.S., vol. xlix, p. 314, 1893.

Before we can consider the question of the high-level gravels of the Thames Valley as being in any way properly dealt with, it is necessary to get as clear a view as possible of the movements of the ice-sheets which invaded this area. This is a difficult matter to accomplish, for British geologists have generally confined themselves to considering the greatest area which can be shown to have been covered by ice and the directions in which it probably travelled; but the trend of the rock striæ and the variable nature of the deposits in some areas show that the direction of the flow changed very considerably from time to time, as also did the areas covered by the ice at different times during what seems to have been the same epoch of glaciation.

One of the most interesting ice-flows is that which passed over the Stainmoor Pass and carried with it the well-known Shap granite. That at one time this ice-flow passed in an easterly direction out into the North Sea is shown by the occurrence of this rock at Elwick, as far north as Hartlepool. This uninterrupted movement of the Stainmoor ice to the east was also shared by that coming through the Tyne Gap.[1] Trechmann shows that the ice from Scandinavia pressed against the English coast between these two lobes. Subsequently the ice from the Cheviots was deflected in a southerly direction by this North Sea ice and passed down the coast. It has generally been considered that this deflection of the British ice-flows was only due to the advancing Scandinavian ice, but it may have been partly due to the waning of the British ice-sheets as the Scandinavian ice advanced and thickened.

Lamplugh[2] shows that further south at Flamborough Head similar changes in the direction of the flow took place, the Basement Clay of Holderness being the oldest and having a Scandinavian origin, whilst the subsequent flow was down the coast. This alteration in the direction of the ice-flow becomes more marked as we reach Central and Western England. In the Trent Valley this change in the direction of ice-flow is very pronounced. Deeley[3] has shown that in this area the ice first came from the west, and that its fluvio-glacial gravels and sands went as far east as Grantham. Subsequently this ice-flow melted away and its place was taken by the "Northern" ice-flow which laid down the Chalky Boulder-clay. One lobe of this flow turned towards the west and passed up the Trent Valley, laying down upon the older boulder-clays and fluvio-glacial deposits the Chalky Boulder-clay and its fluvio-glacial deposits. The ice from the west and that which came down the Derwent Valley advanced into a submerged country, a submergence probably due to the presence of the Scandinavian and Scotch ice in the North Sea. Associated with the hard till with glaciated boulders formed by the early western and Pennine ice, are clean current-bedded sands and gravels not containing flints, and sedimentary clays containing well-glaciated boulders, but no flint.

That this ice-sheet was very thick in the Irish Sea is shown by the

[1] Q.J.G.S., vol. lxxi, pp. 53–80, 1915.
[2] Q.J.G.S., vol. xlvii, pp. 384–429, 1891.
[3] Q.J.G.S., vol. xlii, pp. 437–79, 1886.

fact that one lobe of it passed over the gap in the Pennines near Buxton and distributed Scotch and Cumberland rocks on the high land above Tideswell. At Bakewell, well up the Derwent Valley, there is a good deposit of boulder-clay formed by this ice. The grave-yard stands on it, and heaps of foreign erratics are to be seen there. Another thick deposit of it is to be seen at Crich, where it rests upon a well-glaciated floor of Carboniferous Limestone. So thick was this ice in the Irish Sea, that it completely submerged Snaefell in the Isle of Man, which is 2,034 feet high. Coming from Cumberland and Scotland one lobe of it passed to the east of Wales into the Severn Valley. Here, reinforced by ice from Wales, it pressed against the Cotswold Hills, forming gravels and leaving Northern Drift pebbles on their flanks, such as Millstone Grits and quartzite pebbles, but no flints. Such pebbles and gravels have been found, according to Lucy,[1] at heights of 750 feet above the sea-level. If the ice reached such a thickness there must have been an overflow of water into the Thames Valley through the Andoversford Gap to the east of Cheltenham. Such thick ice would also pass over the Thames watershed into the Evenlode and Cherwell Valleys, and in this way Northern Drift found its way into the upper Thames Valley, where it is now found at heights considerably above the Tilehurst Terrace Gravels. As far as the British ice is concerned this would appear to have been the time of its greatest extension. However, the succession of events which preceded the advent of the Chalky Boulder-clay ice may have been much more complex than is here indicated. There is very little evidence of this in the area we are considering; but in Norfolk, Suffolk, and Northern Essex the complexity of the Drifts is very striking.

Upon the westerly drifts of the Trent Basin there rest the Great Chalky Boulder-clay and its associated gravels and sands. It is clear from the arrangement of the deposits that, before the North Sea ice advanced up the Trent Valley, the Irish Sea ice had retreated a considerable distance. Whether in the Trent Valley to the west of Burton-on-Trent the eastern ice coalesced with that coming from the west is uncertain. Lucy states that along the flanks of the Cotswolds, and running up to the Marlstone Terrace to heights of about 610 feet, there is a line of gravel containing an abundance of chalk flints. Therefore, although the British ice may have been reinforced at this time by the ice which formed the Chalky Boulder-clay, its gravels only reach heights of 610 feet, whereas the earlier British ice formed gravels at heights of 750 feet.

That the Chalky Boulder-clay glacier reached the upper end of the Evenlode Valley is clear; for Lucy states that at Paxford, 3½ miles north-west of Moreton-in-the-Marsh, he saw in a field which was being drained fully five feet of boulder-clay, containing some flints, quartzose pebbles, Lias, greenstone, Millstone Grit, and syenite from Charnwood. At Little Wolford, about 8 miles east of Moreton-in-the-Marsh, in a gravel-pit, were found pebbles of a hard red species of chalk which occurs not infrequently in the Wolds of Yorkshire and

[1] The gravels of the Severn, Avon, and Evenlode, and their extension on the Cotswold Hills.

Lincolnshire. Buckland, many years before, had recognized this red chalk. Another lobe of the Chalky Boulder-clay glacier moved up the Ouse Valley and reached the limits shown in the Map, Fig. 1.

If the above reading of the teaching of the boulder-clays, sands, and gravels be correct, then the first erratics to reach the Thames Basin were brought into the district by the British ice-sheet which reached the more northern and western portions of the Thames Basin, but may not have reached the Ouse Valley or the Lower Thames Valley.

It has been maintained by Tutkowski[1] and others that near the margins of great ice-sheets cold and dry conditions prevail. Outside this dry area the climate, although cold, is much more moist, and the precipitation very considerable. It may be that some of the moisture which does not fall near the ice margin is precipitated on the ice some distance from its edge owing to local winds. To some extent this reduced precipitation at the ice margin is a feature of the Antarctic Continent, for Bouvet Island, although small and out in the open ocean, is completely covered with ice down to the water's edge, whereas the coast of the continent, hundreds of miles to the south, is not ice mantled to the same extent.

It is possible that Great Britain, before the Scandinavian ice first reached it, was outside the dry zone and, like Bouvet Island, suffered intense glaciation, but that as the Scandinavian ice advanced over the North Sea floor towards Britain the dry zone advanced with it, and that when the continental ice-sheet reached our shores the air had become so dry that the local British ice-sheet, partly or wholly, melted away. That such a dry period existed is shown by the discovery of dreikanters[2] in the Midland Counties.

As far as can be made out, all the boulder-clays we have considered seem to belong to one cold period,[3] but this is by no means certain.

It may be that the Bowsey and Ashley Hill gravels and some others to the north-east along the edge of the Chiltern Hills, in the Kennet Valley, and to the north-west of Bagshot, may have been formed by the early outflow water of the British ice-sheet; but that the Thames, as suggested by Sherlock and Noble,[4] then ran past St. Albans in a north-easterly direction scarcely seems probable, nor is it likely that it passed into the Ouse Valley near Buckingham, as suggested by Harmer.

Sherlock & Noble[5] also suggest that the Clay-with-Flints is a glacial deposit, i.e. a boulder-clay. Now, according to the evidence we have, the Clay-with-Flints occurs on those portions of the Chalk escarpment which was never overridden by the Chalky Boulder-clay ice-sheet, and does not occur on those portions which have been overridden. There is a marked difference between the Chalk escarpment to the south-west of Luton as compared with that to the north-east. Sherlock & Noble remark that "an ice-sheet coming from the

[1] *Scot. Geol. Mag.*, March, 1900.
[2] Matley, Q.J.G.S., vol. lxviii, p. 293, 1912.
[3] Q.J.G.S., vol. xlii, pp. 439 and 466, 1886.
[4] Q.J.G.S., vol. lxviii, p. 206, 1912.
[5] Ibid., p. 199.

north and north-west would sweep up these materials and produce a confused mass known as Clay-with-Flints". But from the distribution of the boulder-clay and gravels the ice appears to have come from the north-east. Deep snow on the Chilterns may have modified the deposit. The Clay-with-Flints seems to be such a deposit as we may expect to find filling up surface channels formed by the subsidence of the chalk into underground channels resulting from the solvent action of water, or filling swallow-holes. As the Tertiary beds were removed they would supply material to fill up such hollows as they formed. The brick-earths thus produced rest upon a layer of clay and flints which seems to be a chalk residue. Sarsen-stones were once very probably distributed over the whole area, and where they rested upon the surface they were removed for building purposes centuries ago, or destroyed by atmospheric agencies. They are now only to be found where they were buried.

At Sonning, Smith & Dewey [1] give the height of the Boyn Terrace as 180 feet, and with this deposit they correlate the Dartford and Swanscombe Terraces. As the Tilehurst Terrace is at a height of 275 feet at Sonning, the Boyn Terrace [2] is thus 95 feet lower. Both at Dartford and Swanscombe the gravels lie well within the limits of the Tilehurst Terrace Gravels. They must, therefore, have been formed either before the Tilehurst Gravels were laid down or whilst the River Thames was re-excavating its valley through the fluvio-glacial deposits.

Very few remains have been found in gravels on a level with the Tilehurst Terrace Gravels except to the south of the Thames on the east and west sides of the Darent River. Here at Dartford and Swanscombe mammalian and other remains have been found in considerable numbers. Much further work will have to be done before the age of these mammaliferous gravels can be said to have been settled. The remains they contain seem to show that there is a wide gap between them and the Taplow or Middle Terrace deposits. On this point Hinton [3] says, "Excepting the elephant, rhinoceros, *Felis*, and possibly two of the deer, all the forms mentioned differ from those whose remains are found in the earliest deposits of the next or Middle Terrace of the Thames Valley at Grays, and they approach those occurring in the 'Forest Bed' series and the Upper Val d'Arno Pliocene." It is possible that the Dartford and Swanscombe Gravels are in part, at least, older than the fluvio-glacial gravels, for Leach [4] found in the lower portion of the Dartford Heath Gravel mammalian remains of beasts which it is unlikely lived when the upper portion of the gravel bed was deposited by a river fed by streams coming from an adjacent ice margin.

[1] *Archæologia*, vol. lxiv, p. 178.
[2] *The Geology of the Country around Windsor and Chertsey* (Mem. Geol. Surv.), p. 67.
[3] Proc. Geol. Assoc., vol. xxi, p. 492, 1909–10.
[4] Proc. Geol. Assoc., vol. xxiv, p. 340.

V.—Sedgwick Museum Notes.

Notes on the genus *Trinucleus*. Part IV.

By F. R. Cowper Reed, Sc.D., F.G.S.

The Genal Areas.

THE triangular non-perforated areas lying on each side of the glabella and bounded in front and laterally by the fringe are usually described as the cheeks and distinct from the fringe, as if they alone corresponded to the fixed cheeks of the Opisthoparia and Proparia, or even included also the free cheeks of these orders. But if the facial suture is marginal, and if the lower plate of the fringe is considered to represent the free-cheeks, as Beecher[1] maintained, the upper plate of the fringe must be regarded as merely a modified marginal portion of the fixed cheeks, so that the triangular areas within the fringe would only constitute the inner part of the fixed cheeks.

Whether we regard this view of the homologies of these structures as correct or not (see below), we must note that there is sometimes no sharp demarcation of the fringe from the so-called cheeks, scattered pits (particularly near the genal angles) occurring within the generally regular inner limits of the fringe, as for instance in *T. concentricus* of the Onny River (Geol. Mag., Dec. V, Vol. IX, p. 349, Pl. XVIII, Fig. 4, 1912).

It is, however, convenient to describe these so-called cheeks apart from the fringe, the characters of which have been discussed on a previous occasion (op. cit.), and we may accordingly term them the *genal areas* to avoid confusion and premature conclusions.

There are three more or less distinct types of genal areas recognizable amongst the species of *Trinucleus*, i.e.:

1. Genal areas divided into two more or less unequal portions by an oblique ridge or line of bending, each portion having a different surface ornamentation, e.g. *T. Murchisoni*, *T. Gibbsi*, *T. Etheridgei*.
2. Genal areas marked with a horizontal or slightly oblique line ("ocular ridge" or "line") running outwards from the side of the glabella to a median or submedian tubercle ("eye" or "ocular tubercle") and sometimes beyond it. The ornamentation of the surface is uniform. E.g. *T. seticornis*, *T. Bucklandi*.
3. Genal areas without any ridge or line, uniformly convex, without "ocular tubercle". The ornamentation of the surface is uniform. E.g. *T. concentricus*.

These three types may now be described in detail, and their development and relations studied in various species.

1. In *T. Murchisoni*, Salter (see Geol. Mag., Dec. VI, Vol. I, p. 352, Pl. XXVIII, Figs. 4, 4*a*, 1914), a narrow semilunar area stretches along the inside of the fringe from the pseudo-antennary pits at the front end of the glabella to the postero-lateral outer angle of the genal area, and is marked off from the rest of the genal area

[1] Beecher, Amer. Journ. Sci., ser. IV, vol. iii, pp. 100, 103, 183, 186, 1897.

by a nearly straight oblique line along which the surface is bent or angulated. The semilunar outer band thus formed slopes down more or less steeply to the fringe, and is differentiated from the rest of the genal area. The line of angulation is marked at its posterior end by a short ridge forming its crest, beyond which lies a deep pit in the pleuro-occipital furrow. Salter[1] considered that this line of angulation occupied the place of the facial suture of other trilobites.

The semilunar outer band is smooth in the species *T. Murchisoni*, but the whole of the inner portion (with the exception of a narrow region alongside the basal part of the glabella) is covered with a coarse reticulation of fine raised lines which arise as a fan-like group of thicker lines radiating from a small notch behind a tubercle projecting into the axial furrow at the level of the first lateral furrow of the glabella. These radiating lines rapidly break up into the general reticulation of the surface, so that the radial arrangement is almost lost. The pseudo-frontal lobe of the glabella, which possesses a median tubercle, has similar fine reticulation, but anteriorly the meshes are elongated transversely so as to be roughly concentric to the front end; posteriorly they became hexagonal or polygonal like those on the genal areas. The small inner portion of the genal area on each side of the base of the glabella is only minutely granulated, which is significant (see below).

In *T. Gibbsi*, Salter, and *T. Etheridgei*, Hicks, the angulation of the genal areas and differentiation into two portions exhibit the same general characters. But in the former species the angulation is sharper and the outer band narrower, and the fan-like arrangement of the reticulating lines on the posterior part is not so clear.

In *T. Etheridgei* the genal areas are divided into two nearly equal parts by the angulation, but it is less sharply marked and often nearly obsolete. The different superficial characters of the two parts are, nevertheless, retained. No definite point of origin for the reticulations can be recognized in this species, a general honeycomb-like meshwork existing all over the inner region with the exception of the inner posterior angle alongside the base of the glabella, which is smooth. A median tubercle is usually visible on the pseudo-frontal lobe of the glabella. In none of these three species is there a definite ocular ridge or ocular tubercle on the genal areas.

It appears probable that we may correctly compare the radiating and reticulating lines on the surface of the genal areas with the so-called nervures or veins on the cheeks of *Dionide* (although their radiating arrangement is better preserved in the latter genus), for they arise from the same point on the axial furrows. Similar structures having an identical origin are found in the cheeks of many Cambrian genera, which are devoid of compound eyes, e.g. *Erinnys*, *Elyx*, *Liocephalus*, and other members of the Conocoryphidæ.

Beecher regarded the meshwork and lines as belonging to the nervous system, but Lindström[2] considered them as ramifications of the circulatory system, the larger lines being the main vessels and

[1] Salter, Mem. Geol. Surv., vol. iii, 2nd ed., p. 516, 1881.

[2] Lindström, Kongl. Svensk. Vet. Akad. Handl., Bd. xxxiv, No. 8, pp. 18–20, 31–3.

the smaller ones representing capillaries and venules as suggested by the genus *Limulus*. It can hardly be doubted that the general reticulation of the surface is not merely a superficial ornamentation of the shell of no functional importance, particularly when we are able to trace its direct connexion with a definite group of radiating vessels always arising from the same spot on the axial furrows.

The small smooth or differently ornamented regions close to the base of the glabella suggest the 'alar areas' of *Harpes* and *Dionide*, which are also traceable in some species of *Ampyx* and are found clearly developed in larval stages of *Trinucleus* as Beecher[1] demonstrated.

The nature and history of the semilunar outer band in front of the angulated line crossing the genal areas is intimately bound up with the whole interpretation of the structure of the head-shield of the genus. But before discussing this vexed question it will be best to describe the characters of the two other groups into which I have divided the species according to their genal features.

It may, however, be naturally expected that in the earliest representatives of the genus which are comprised in my first group, and are confined to the Arenig and Llandeilo Beds, we should find the evidence of its affinities and original structure. Later species in the stratigraphical succession would be expected to diverge more from the primitive stock and to have suffered additional modification.

There is a link connecting the first group with the second, and it is found in the species *T. fimbriatus*, Murchison, the position of which is intermediate. For it has no division of the genal areas into two parts by a line of angulation, their surface being gently and uniformly convex; there is no ocular tubercle and no typical ocular ridge, though Salter[2] and McCoy[3] put this species in the genus *Tretaspis*, which is characterized by their possession. The diagonal facial suture which McCoy[4] clearly represented in his figure does not exist. There is, however, a small tubercle in young individuals[5] situated in the axial furrow opposite the first lateral furrow of the glabella, just as in *T. Murchisoni*, but there is no such definite group of nervures radiating from it over the genal area. We may, however, observe that near the posterior lateral angles of the genal areas the interlacing sinuous lines, which form the reticulations on the surface, converge and are grouped together to form larger, more elongated meshes directed towards a small tubercle near the posterior border with a pit in the pleuro-occipital furrow, as in *T. Murchisoni*. The inner posterior angles are also nearly smooth with very faint or obsolete reticulations, thus affording traces of the 'alar areas'. The rest of the genal areas is covered with a polygonal or hexagonal fine meshwork.

The French species *T. Bureaui*, Oehlert,[6] which seems to belong

[1] Beecher, Amer. Journ. Sci., ser. III, vol. xlix, pl. iii, figs. 1, 2, 1895.
[2] Salter, Dec. Geol. Surv., vii, pl. vii, fig. 8, 1853.
[3] McCoy, Syn. Brit. Pal. Foss. Woodw. Mus., p. 146.
[4] Ibid., pl. i E, figs. 16, 16*a*.
[5] Reed, GEOL. MAG., Dec. VI, Vol. I, Pl. XXVIII, Fig. 3, 1914.
[6] Oehlert, Bull. Soc. géol. France, ser. III, vol. xxiii, p. 308, pl. i, fig. 7, 1895.

here, is of interest from possessing two well-developed raised nervures on the genal areas, starting from a point on the axial furrow alongside the pseudo-frontal lobe, and then diverging as they cross the genal areas to converge and unite a little in front of the posterior lateral angle. These structures are undoubtedly of the same nature as those described in *T. Murchisoni* and *T. fimbriatus*, having the same point of origin, same general course, and same point of termination; and they bear a specially close resemblance to the nervures on the cheeks of *Dionide Lapworthi*, Etheridge, jun., and Nicholson,[1] from the Whitehouse Group of the Girvan district. The rest of the genal surface of *T. Bureaui* is said to be smooth or minutely punctate, and no reticulating lines are described. Ocular tubercles are absent.

2. We pass now to consider the typical members of the second group in which a definite ocular ridge and ocular tubercle is developed in each genal area. These structures find their expression in most of the members of McCoy's genus *Tretaspis*. The ocular ridge starts at the level of and opposite the first lateral furrow of the glabella, and thus corresponds in place of origin with the marginal tubercle and commencement of the radiating lines in *T. Murchisoni* and its allies. Usually the ridge ends in a small tubercle called the ocellus or ocular tubercle by most authors, and it may run out at right angles to the axial furrows or be directed rather obliquely backwards towards the postero-lateral angle. It is occasionally continued beyond the ocular tubercle to this point with diminished strength, as may be seen in the smaller specimens from Thraive Glen, Girvan, which are attributed to *T. Bucklandi*, Barr. In these this extension of the ridge ends against the fringe a little in front of the postero-lateral angle of the genal area. Nicholson & Etheridge, jun.,[2] noticed and described this feature in this Scotch species, and the present author[3] has also described it in *T. subradiatus* from the same area. Ruedemann[4] has observed its occurrence also in *T. reticulatus*, Ruedemann. The inner and outer portions of the ocular ridge do not correspond in position or course with the line of bending which crosses the genal areas in the first group; but as above pointed out the point of origin of the ocular ridge coincides with that of the group of nervures.

Not only may the outer portion or extension of the ocular ridge disappear, as is the case in the large form of *T. Bucklandi* from Girvan, but the inner portion between the axial furrow and ocular tubercle may likewise become obsolete, leaving the latter isolated. Since the young of *T. concentricus* (Eaton) possesses an ocular ridge (but not its extension) as well as an ocular tubercle, according to Beecher,[5] both structures have been held to be phylogenetically primitive characters; and if this is so the loss of the outer and inner

[1] Reed, *Girvan Trilobites* (Palæont. Soc.), pt. i, p. 25, pl. iv, fig. i, 1903.
[2] Nicholson & Etheridge, Mon. Silur. Foss. Girvan, fasc. 2, p. 191, 1880.
[3] Reed, *Girvan Trilobites*, pt. i, p. 12, pl. ii, figs. 1–6, 1903.
[4] Ruedemann, Bull. 49 New York State Museum (1901), Palæont. Papers 2, p. 41, pl. iii, figs. 11, 15–20.
[5] Beecher, Amer. Journ. Sci., vol. xlix, p. 309, pl. iii, 1895.

portions of the ocular ridge mark a more advanced stage in development. To this question we will return later. With regard to the function of this structure Beecher (op. cit.) remarked that "from the direction of the optic nerve in *Limulus* and its relations to the surface features of the cephalothorax, the eye-line [= ocular ridge] probably represents the course of that nerve". The Bohemian examples of *T. Bucklandi*, according to Barrande, do not possess an ocular ridge, the ocellus being isolated on the genal area.

It may be suggested that the ocular ridge in this Group 2 with its outward extension represents a specialized and concentrated nerve-supply and corresponds to a specially enlarged nervure of the diffuse radiating bundle of nervures in Group 1. Its presence is probably correlated with that of the ocelli; and the absence of visual organs in Group 1 seems to be connected with the breaking up and irregular extension of the nerves over the whole surface, since we find a similar condition in many blind Conocoryphidæ. In the large Girvan examples of *T. Bucklandi* in which the ocular ridge is obsolete the reticulating lines which cover the genal areas with a polygonal meshwork start as radiating or sinuous nervures from the same point on the axial furrows as the ocular ridge and as the corresponding nervures in Group 1. The extension of the ocular ridge to the postero-lateral angles which, as above-mentioned, occurs in several species may likewise be the concentration of the nerve-supply which in Group 1 and *T. fimbriatus* is split up into a convergent group of fine lines. The phylogenetic significance of these structures is discussed below.

A few remarks may here be made on the puzzling variations in the development of the meshwork on the genal areas which is found in this second group. The surface in some cases is covered with the reticulating ornament, but in other cases appears smooth or punctate; and internal casts likewise differ much in their appearance. These peculiarities amongst individuals of the same species or members of the same group are due to the existence of more than one layer in the shell and to the difference in the characters of the outer and inner surfaces of these layers.

It seems that there are two layers to the shell, the outer one of which has an externally smooth or punctate surface, and is usually very thin and easily abraded, so that it is frequently missing from even well-preserved specimens. The second or inner layer bears on its upper surface (which is in contact with the lower surface of the outer layer) the raised lines of the reticulating nervures, while the lower surface of the inner layer is only minutely granulated or smooth, the interlaminar nervures rarely showing through it. When, however, this inner layer is thin and the nervures stout and strong, we find the reticulations showing through, and therefore impressed on the internal cast of the head-shield, the hexagonal or polygonal cells being represented as shallow pits, as can be seen in casts of *T. Bucklandi* from Girvan or of *T. seticornis* from various English and Welsh localities. The nervures do not seem usually to project as raised lines on the inner surface of the inner layer; and the ocular ridge and tubercle are certainly hollow, for these structures show respectively as a groove and a pit on internal casts. When

the inner layer is thick and granulated, the internal cast is covered with corresponding small punctæ. Barrande[1] was much puzzled with these different appearances of the cheeks and glabella, and did not offer any satisfactory explanation of them.

3. In the third group into which I have arranged the species according to their genal characters, the adults have no ocular ridges and no ocular tubercles, and the reticulating nervures seem also to have disappeared, the shell being smooth and the interlaminar surfaces showing no meshwork, though punctæ or minute granulations may be present. But in some of the largest specimens of *T. concentricus* from the Onny River there are faint relics of the meshwork. The internal casts as well as the external surface of the shell only show minute pits or granules as a rule. In the young of *T. concentricus* the ocular ridge and ocellus of the species of Group 2 are present, according to Beecher, so that their loss seems to be a secondary modification or a suppression of larval characters; for the stratigraphically later group of *T. seticornis* possesses them.

(*To be concluded in our next Number.*)

NOTICES OF MEMOIRS.

I.—The Heterangiums of the British Coal-measures. By Dr. D. H. Scott, For. Sec. R. S.

WILLIAMSON, in his published papers, only recognized two British species of Heterangium, *Grievii* and *H. tiliæoïdes*. Under the former name he included not only the Lower Carboniferous plant from Burntisland, on which the species was founded, but also certain Coal-measure forms from Dulesgate. In the joint work by Williamson and the present author the same nomenclature was adopted, but a second form from Dulesgate was also described under the provisional name *H. cylindricum*.

H. tiliæoïdes, a Coal-measure species from Halifax, remarkable for the great development and perfect preservation of the phlœm, has been kept distinct ever since its first discovery in 1886.

The enormous difference of age between the Burntisland and the Dulesgate plants rendered their specific identity highly improbable, and the latter has been separated under the name *H. Lomaxii*, originally suggested by Williamson himself, after the name of the discoverer, though not published. *H. Lomaxii* is characterized by the great distinctness of the primary xylem-strands, by their nearly exarch structure, with little primary centrifugal wood, by the abundant secretory sacs of the stele, and by the rather scattered leaves.

In the Dulesgate material several forms of Heterangium stem have been found in association; it is unlikely that they are specifically distinct—they more probably represent axes of different orders. The provisional species *H. cylindricum* differs in no important respect from *H. Lomaxii*, to which it should be reduced.

[1] Barrande, *Syst. Silur. Bohême*, vol. i, Trilob., p. 622; ibid., Suppl., p. 47.

A very fine Heterangium from Shore was discovered by Mr. Lomax and his son in 1912. It is of large size, at least 17 mm. in diameter, though without secondary growth. The plant was originally compared with the so-called *H. cylindricum*, but is at least as close to *H. tiliæoïdes*. The feature which at first seemed to be most striking is the fact that four distinct leaf-trace bundles enter the base of the leaf, each of them dividing into two in the petiole. This is certainly the best example yet found of a polydesmic petiole in Heterangium, and shows an interesting approach to the Medulloseæ in this respect. We may also compare Dr. Gordon's new genus *Rhetinangium*. However, there is reason to believe that most of the British Coal-measure Heterangiums were polydesmic. In *H. tiliæoïdes* there are four distinct bundles in the petiole, and the same was the case in *H. Lomaxii*.

In all these plants two bundles start from the stele to form the leaf-trace, dividing into four, at least in some cases, before entering the leaf-base. Only in a very small stem from Dulesgate (not associated with *H. Lomaxii*) did a single bundle leave the stele (as in the Burntisland species), dividing into two on its outward course. This little stem has nothing to connect it with any other form and may be distinguished as *H. minimum*.

H. tiliæoïdes is maintained as a distinct species, mainly on the ground of its highly developed phlœm with dilated medullary rays. In the behaviour of the leaf-traces it comes very near the Shore plant, which may, for the present at least, be kept distinct under the name *H. shorense*.

II.—Note on the Geology of Porcupine.[1] By J. B. Tyrrell.

I HAVE been asked on two or three occasions whether I consider that the gold-bearing quartz veins in Porcupine are formed by the filling of fissures or by replacement of the rock in which they occur, and I have told individual members of an instance where bodies of quartz were undoubtedly introduced into similar pre-Cambrian rocks by metasomatic replacement, but some others among those present might be interested in hearing of the instance, so I will mention it. In the West Shining Tree country greenstones showing strongly marked ovoidal or pillow structure, similar to that so common in the amygdaloidal basalts of this district, are particularly abundant, and here and there through the greenstone quartz veins occur, some of which have been determined to contain gold. The individual ovoids or pillows are packed closely together, but there are angular portions of the greenstone in between them, and, as a rule, the rock inside the pillows and in the angular areas outside of them are almost precisely similar in character. In one place, however, the angular areas are entirely converted into quartz, which, as far as I could see, was precisely similar to the quartz in the veins near by. As these angular areas had originally been greenstone, we have in them a clearly marked example of a metasomatic replacement

[1] Extract from the Monthly Bulletin of the Canadian Mining Institute, June, 1915, pp. 397–8.

of the greenstone by quartz, but whether the veins in the vicinity were also formed by a similar replacement or not, I have no definite proof, but I believe that replacement took a large share in their formation. A number of the members here may think that such questions have no bearing on mining problems, and I have often heard men say that they did not care how the gold got into the rocks, that all they were interested in was where it was. Now the world has advanced too far to ignore the causes of things; if those things are to be clearly understood and if you are to clearly understand the bodies of ore which you are working you cannot afford to ignore the question of the causes which lead to the formation of those ore bodies, since a knowledge of those causes may enable you to correctly predict the extensions of those ore bodies or may point you to where other similar ore bodies occur.

REVIEWS.

I.—Geology of the Federated Malay States. Geologists' Annual Report for the year 1914. By J. B. Scrivenor, Geologist F.M.S.

EARLIER reports, e.g. that for the period September, 1903, to January, 1907 (reviewed in the Geological Magazine, 1907, pp. 565–7), have given British geologists an opportunity of becoming acquainted with the general geology of the Federated Malay States, while Mr. Scrivenor's finely illustrated report, *The Geology and Mining Industry of the Kinta District, Perak* (1913), has described the district which is most interesting and important both geologically and economically. The present report, which deals principally with economic questions, is a record of steady progress, though it does not include any startling discoveries. There is only a brief reference to the field work of Mr. Scrivenor in mapping the Batang Padang district. Such work is bound to be carried out under many difficulties in view of the climate and of the dense vegetation which covers so much of this country.

Mr. Scrivenor took the opportunity of accompanying the district officer of Upper Perak in a journey to the little-known region near the headwaters of the Perak River. He briefly describes the country as an area of granite at no great elevation, supporting masses of altered bedded rock with quartz porphyry and basic volcanic rocks.

The report shows that the chemist, Mr. C. Salter, has been occupied with economic work, chiefly assays for minerals, but including also a number of analyses. It is satisfactory to learn that Mr. Scrivenor is getting together a collection of photographs illustrating the geology of the country.

The author describes a successful attempt to replace the diamond by local corundum for drilling purposes. A consignment of kaolin was shipped to Europe in order to ascertain if it could be used for pottery. Unfortunately, owing to the War, half the consignment failed to reach its destination.

Not much further information is given concerning the greatest industry of the peninsula, that of tin-mining, and no further light is

thrown on the question of the age and origin of the tin-bearing clays of the Kinta district, concerning which Mr. Scrivenor's former assistant, Mr. W. R. Jones, is in disagreement with him.

There is a brief account of gold workings under native management. The statement that certain men "obtained in a season 2–3 katis of gold per party of three men. This is equal to 24–36 bungkals of gold" does not convey much information to the average reader of the report at home. Such words as *pikul* and *ulu* might also with advantage be explained in a footnote.

II.—The Interior of the Earth.

Certain Hypotheses as to the Internal Structure of the Earth and Moon. By Harrold Jeffreys, B.A., M.Sc. Mem. Roy. Ast. Soc., lx, pt. v, pp. 187–217, 1915.

The Viscosity of the Earth. By H. Jeffreys. Monthly Notices Roy. Ast. Soc., lxxv, pp. 648–58; lxxvi, pp. 84–6, 1915.

The Mechanical Properties of the Earth. By H. Jeffreys. The Observatory, No. 491, pp. 347–51, 1915.

THE gradual refinement of geophysical methods of research during recent years has resulted in the accumulation of quite a considerable fund of information relating to the interior of the earth. The known data from which our present knowledge is derived are—(1) the value of the precessional constant, (2) the earth's superficial ellipticity, (3) the period of the variation of latitude, (4) the observed heights of oceanic tides, (5) the lunar deflection of gravity, and (6) the velocities of earthquake waves. Using the results available from these sources, Mr. Jeffreys discusses those hypotheses that regard the earth as consisting primarily of a metallic core surrounded by a rocky shell, particularly from the point of view of determining the distribution of rigidity and density. He shows that neither the outer shell nor the inner core can be permanently rigid, and that the only conclusion consistent with the facts is that the earth as a whole is plastic. Again, the only distribution of density conformable with this conclusion is that of Wiechert, viz. a shell of density 3·2 surrounding a core of density 8·2 having a radius equal to 0·78 that of the surface. These figures are, of course, closely in accordance with the densities of stony and iron meteorites, and with the facts deduced from the seismic exploration of the earth's interior. That the rigidity of the core is at least twice that of steel is a necessary consequence of the effect of pressure, if the main constituent of the core is metallic iron.

Mr. Jeffreys shows that the lithosphere has the hydrostatic form to a high degree of accuracy. This fact, combined with the deduction that the earth's rotation was originally faster than now, leads us to conclude that the outer shell (at least) must have periodically adjusted itself to the hydrostatic form. Chamberlin has rejected this view, partly because it seems to imply that mountain ranges—particularly the older ones—should be meridional in their alignment. However, it seems to the present writer that the greatest adjustment may have occurred in a period antecedent to any now recognized. Such

adjustment, if accomplished mainly by movements of igneous magmas, would well explain the north to south elongation of the continents. Moreover, in this way one can understand the predominance of granitic rocks in the lighter continental segments, as compared with the suggested paucity or even absence of granitic rocks from the heavier oceanic segments.

In his consideration of the moon, Mr. Jeffreys finds that the period of revolution at the time of its consolidation was of the order 6·5 days. An important conclusion to which he arrives is that the strains within the moon can never have been sufficient to produce permanent set. It thus becomes difficult to believe that tidal friction has been responsible for the moon's present attitude towards the earth. In the second paper it is shown that the moon's empirical secular acceleration leads to such a value for the plasticity of the earth that the Eulerian nutation (responsible for variation of latitude) ought to die down in a few days. One explanation of the obvious discrepancy would be that tidal friction is not the main factor now concerned in the control of the moon's secular acceleration.

It is interesting to notice that none of these investigations prove a formerly molten earth, though it is safe to say that with such an assumption the present status and behaviour of the earth and moon can be most easily explained.

ARTHUR HOLMES.

III.—(1) ON SOME FOSSIL MAMMALS FROM SZE-CHUAN, CHINA. (2) ON SOME FOSSIL MAMMALS FROM HONAN, CHINA. (3) ON SOME FOSSIL MAMMALS FROM TSUKINOKI, UGO. By H. MATSUMOTO. Reports of the Tohoku Imperial University [2], Geology, vol. iii, No. 1, 1915.

THE first of these papers deals with mammalian remains from the late Pliocene and early Pleistocene deposits. From the former two species of *Stegodon* are recognized, together with a Rhinoceros and several Bovine animals, one of which is referred to a new genus *Proboselaphus*. From the latter horizon a new form of Hyæna, *H. ultima*, and two species of Rhinoceros are described.

The second paper describes a number of Pleistocene mammals, including a large species of *Equus*, regarded as new, two species of deer, and a small Bison, referred to a new species under the name *Bison exiguus*. There is also a human sacrum which is said to resemble in several respects the sacrum of the Chapelle-aux-Saintes man described by Boule.

The last paper gives an account of a series of mammals from the Pleistocene of Japan, including *Elephas namadicus* and a new species of pig, *Sus nipponicus*, in some respects intermediate between *Sus taiwanus* and *S. leucomystax*.

The above papers, which are published in English, are beautifully illustrated by a series of nineteen plates, for the most part unusually good photographs, and some text-figures.

IV.—Mammoths and Mastodons. By W. D. Matthew. No. 43 Guide Leaflet, American Museum of Natural History, November, 1915.

In this guide leaflet Dr. Matthew has given a very interesting outline of our present knowledge of the Proboscidea, referring especially to the specimens exhibited in the American Museum of Natural History. He commences with a short historical account of the early discoveries of elephant remains, and then passes on to a brief description of the various extinct elephants, the American Mastodon, and the Tertiary Mastodons, concluding with a discussion on the early ancestors of the group and the general course of its evolution. One of the most interesting sections is that relating to the American Tertiary Mastodons, concerning which much more information than has yet been published is desirable. The author revives several forgotten generic names, e.g. *Gomphotherium* and *Rhynchotherium*, in the last case mentioning no species. Probably, however, the species described in this Magazine ([5] Vol. VI, p. 347, 1909) under the name *Tetrabelodon dinotherioides* should be placed here, the symphysial part of the mandible being deflected in the manner said to be characteristic of the genus. *Mœritherium* is not regarded as a direct ancestor of the Proboscidea, but, although it may be a side branch, its Proboscidean affinities appear to be incontestable.

The pamphlet is illustrated with a plate and eleven text-figures.

V.—New Eurypterid Horizon.—A Eurypterid in the Barton Beds! Sounds startling. And a coral-reef too!—Gently, gentle reader, these Barton Beds are in North America. Oh! But then, you will say (after some research) they are Stevenson's Barton group in the Carboniferous of Pennsylvania. No, they are in Ontario, south of that superbly patriotic city Hamilton, and they lie at the very top of the Niagara formation. Fortunately Mr. M. Y. Williams (Oct., 1915, Canada Geol. Surv. Mus. Bulletin, No. 20) now proposes for them the name Eramosa beds, because their dark bituminous dolomites and shales are well exposed along the Eramosa River between Rockwood and Guelph. The importance of these beds lies in their palæontological evidence of a conformable passage from the Niagara to the Guelph formations. The Eurypterid, *Eusarcus logani*, n.sp., is based upon various fragments, and since these are associated with fossils of marine origin, Mr. Williams believes that the arthropods "lived in an entirely marine habitat", a conclusion that would have been less open to criticism had the fragments been less fragmentary.

In the descriptions of species contained in these excellent Bulletins, would it not be possible to give some indication of their systematic position? How many geologists, or even professed palæontologists, can say off-hand what *Lichenalia concentrica* is? Mr. Williams tells them that the surface is undulatory and bears radial and concentric striæ about 0·5 mm. apart; but he leaves them to their own devices to find out that it is a Cyclostomatous Bryozoan, closely allied to *Fistulipora*.

VI.—Effects of Drought in the Waterberg, Transvaal.—The Smithsonian Report for 1914 has reprinted from the Agricultural Journal of South Africa a paper by E. N. Marais on the effects of drought in the Waterberg, which has converted over 4,000 square miles of the Northern Transvaal, an area equal in extent to the Orange Free State, once rich in orange groves, and formerly "a sort of lotus land of fertility, literally overflowing with milk and honey", into an absolute desert "in which there is no single drop of water running or stagnant above the surface of the ground". He says the Limpopo River is now dry throughout this district, and water can only be obtained from it by deep sinking in its bed. All the ordinary springs are empty, and it is only the thermal springs which are still flowing; they show no change in volume, though the loss of their water between the spring and the dam is 60 per cent greater than formerly. The animals have changed their habits or been exterminated; the vegetation is dead, and most of it has disappeared. The author refers to the hope that this extreme drought may mark the greatest swing of the pendulum towards desiccation and may be followed by improvement; but he remarks that every fact observed indicates that the change is permanent, and "that the oscillations of the pendulum are gradually lessening round the dead point". He regards this desiccation of the Northern Transvaal as part of a climatic change, which in the last fifty years has turned thousands of square miles of once fertile territory in Asia into desert. Mr. Marais' descriptions are more graphic than convincing. His statement as to the habits of baboons are either exaggerated or refer to a local peculiarity; and it is difficult to take many of the author's statements seriously, as when he warns us that on the drying up of Lake Rudolf, "that most perfect diadem in the girdle of the globe . . . largely depends the fate of the Nile and of fertile Egypt." Lake Rudolf contributes no more water to the Nile than it does to the Mississippi, and as the author's African geography is so imperfect his conclusions on Asiatic climate do not carry weight.

VII.—Climate of Geologic Time.—Professor Schuchert's "Climate of Geologic Time" has been reprinted from Huntington's *Climatic Factor* (1914, pp. 265–89) in revised form in the Smithsonian report for 1914, pp. 277–311. The paper is a valuable summary of the chief factors as to the past variations in climate. There are no references, but as the authors' names are quoted the authorities can be easily traced. The literature on the subject is so scattered that some is omitted, and the knowledge displayed from different parts of the world is unequal, but probably no geologist, even though specially interested in this question, can read the paper without finding much fresh information. The author insists that the South Australian Boulder-clays are pre-Cambrian instead of Cambrian, and accordingly holds that there is no evidence of refrigeration of climate in Cambrian times. He accepts the view that "the typical glaciation", including perfect roches moutonnées and thousands of perched blocks in Western Ross and Sutherland are due to a pre-Cambrian and not to the

Pleistocene glaciation. He adopts from palæontological evidence great climatic variations in the Mesozoic, but regards Neumayr's Jurassic climatic belts as rather faunal realms. A universal warm climate in the Middle Jurassic he claims from the far northern distribution of coral reefs and marine saurians, though why the saurians could not have lived in cold water, and the locality of the far northern Middle Jurassic coral reefs, is not stated. The identity of the tree ferns in Western Antarctica and Yorkshire does not appear to necessitate a universal warm climate, especially considering Hooker's emphatic warning against trusting to ferns as climatic guides. The paper is of chief value as a summary of the opinion of one of the most competent authorities on palæontological evidence as to former geographical conditions. He concludes that there have been at least seven cool and four Glacial periods in the earth's history, and that these were short in comparison with the intervening warm periods. In discussing the causes of the climatic changes he rejects volcanic dust as a primary factor, and also variations in the amount of carbon dioxide in the atmosphere. He regards the most probable cause as geographic changes due to rhythmic alteration in the earth's topography, and he regards favourably the conclusion that there has been a periodic alternate heaping up of the ocean waters in the equatorial and Polar regions. He asks in conclusion, "are we not forced to conclude that the earth's shape changes periodically in response to gravitative forces that alter the body forms?"

VIII.—The Glacial Anticyclone.—The growing belief that the former glaciations are to be explained by changes in the atmospheric circulation and especially by the influence of great stationary anticyclones is supported in an interesting paper by Professor W. H. Hobbs, "The Role of the Glacial Anticyclone in the Air Circulation of the Globe" (Proc. Amer. Phil. Soc., vol. liv, No. 218, pp. 185–225, 1915). Professor Hobbs is already well known as one of the upholders of this view, and he here discusses the bearing of the recent results from Antarctica and those collected by expeditions across Greenland which have not received adequate attention. Antarctica appeared at first opposed to this explanation owing to the belief that a great permanent cyclone lay around the South Pole. So strongly was this view accepted that Meinardus of the German Antarctic Expedition predicted that the interior of the Antarctic continent was bare and snowless. Meteorologists cling tenaciously to the South Polar cyclone. The results of the National Antarctic Expedition on this question were ambiguous owing to doubt as to whether the critical wind directions recorded were from the true or the magnetic south, directions which there are almost directly opposite. The work of the later expeditions has replaced the supposed South Polar cyclone by an anticline and has shown the existence of a powerful föhn effect around Antarctica, as is there also around Greenland. Professor Hobbs discusses the observations of the Swiss expedition under de Quervain, who in 1912 crossed Greenland from west to east between latitude 66° and 68° N.; and of the German expedition under Koch and

Wegener, which in 1912–13 crossed between latitudes 72° and 73°. Professor Hobbs' valuable memoir indicates that glacial geology will be advanced most from recent Polar work by the meteorological evidence.

IX.—Sketch of the Life of Eduard Suess (1831–1914). By P. Termier. Smithsonian Report, 1914, Publication 2353, pp. 709–18.

THE Smithsonian Report for 1914 (pp. 709–18) includes a translation of the admirable sketch of Suess by Professor Termier, the Continental geologist who most approaches Suess in what has been called his geopoetic style. Professor Termier's sympathetic and luminous eulogy lays stress on Suess' Jewish origin, on the difficulties he encountered as a student in Vienna, which nearly drove him into commercial life, on his useful service in the municipal and national politics of Austria, on his two works, *Die Enstehung der Alpen* and *Das Antlitz der Erde*, and on the intuitive nature of his mental methods. Professor Termier insists that the volumes of the *Antlitz* "contain scarcely any theories". The author, he says, "does not seek to explain or convince—he shows." He defends Suess from the criticism that on many controversial questions he adopted an indecisive and timid attitude, on the ground that Suess was never a theorist, that he did not care to argue on scientific matters, for he was content with seeing, and, having seen, with showing. He claims that Suess "did not say all, he made few personal observations, he did not foresee everything, but by his intuitions, truly those of a genius, of relations and their causes, he incited, prepared, made possible decisive observations, observations which have revolutionized our ideas and illuminated our knowledge".

J. W. G.

X.—Bibliography of Yorkshire Geology. Forming Proceedings of the Yorkshire Geological Society, vol. xiii. C. Fox-Strangways' Memorial Volume. By T. Sheppard. 8vo; pp. xxvi, 630. London, Hull, and York, 1915. Price 15*s.* net.

AT the time of his death Mr. Fox-Strangways had accumulated an incomplete MS. towards a Bibliography of Yorkshire Geology from 1534 to 1892. This has been revised and brought up to 1914 by Mr. Sheppard of Hull, who has for many years contributed annual lists to the *Naturalist*. That it should be printed and issued by the Yorkshire Geological Society is an evidence at once of its value and the wisdom of that Society. Yorkshire geologists have now an encyclopædic work to hand to further their efforts and to save their time. Works are arranged chronologically, then follows a list of the maps and sections of the Geological Survey, and finally an index of 130 double-column pages which gives subjects and localities much in the same way as the Annual Lists of Literature received by the Geological Society of London. It will be of extreme value to all local workers and scarcely of less to those at a distance,

and is a really noble monument to Mr. Fox-Strangways, who did so much for Yorkshire geology. Mr. Sheppard has performed his share well, and thanks are especially due to him for undertaking so heavy an addition to his many burdens. We only wish so excellent an example will have imitators in many other of our county societies, for bibliography is a very sure and certain method of helping others and preventing duplication of work.

XI.—Silurian of the Lower Saskatchewan.—From the Grand Rapids, from Cedar Lake, and from cuttings along the recently constructed Hudson Bay railway, various Silurian horizons are reported on by Dr. E. M. Kindle (Oct., 1915, Canada Geol. Surv. Mus. Bulletin, No. 21). Among Brachiopods two new species of *Leptæna* (*L. sinuosa* and *L. parvula*) are described from beds of late Silurian age, equivalent to the Stonewall Limestone. A dolomite near the base of the Silurian at Grand Rapids abounds in *Conchidium decussatum*. The numerous ventral valves of this Pentamerid show variation in three well-marked directions, but intermediate forms are so numerous that no distinct varieties can be recognized. In a word the variation appears continuous. The spondylium reaches approximate maturity at an early stage, but the radiating folds continue to increase in strength and number down to extreme old age.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *December* 15, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

Dr. Aubrey Strahan, F.R.S., gave an account of a deep boring which was made in 1913 in search of coal, in the parish of Little Missenden, at an elevation of 459 feet above sea-level. The collection of specimens and the identification of fossils was carried out by Mr. J. Pringle. For the first 1,200 feet the hole was punched, and nothing is known of the strata traversed down to that depth—beyond the fact that the boring started in the top of the Middle Chalk and passed through some Oxford Clay and, below that, some oolitic limestones which presumably belong to the Great Oolite Series. From 1,200 feet the hole was drilled for 64 feet, and cores were preserved. The cores consisted of alternations of limestone and mudstone, with a rich and characteristic Upper Ludlow fauna. Among the fossils was *Orthoceras damesi*, Roemer [? Krause], which had not previously been obtained in this country.

The boring serves to fix part of the northern boundary of the tract of Old Red Sandstone which underlies London. It is intended to publish a full account in the next issue of the Summary of Progress of the Geological Survey.

2. *January* 5, 1916.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The Secretary read the following communication:—

"The Islay Anticline (Inner Hebrides)." By Edward Battersby Bailey, B.A., F.G.S., 2nd Lieut. R.G.A.

The observations made by Peach, Wilkinson, Thomson, Macculloch, and others in regard to the 'Schistose Islands' of Scotland are passed in review, and many of them confirmed. In certain directions, however, new interpretations are offered. The following suggestions are among those put forward:—

1. An important fault, perhaps the Great Glen Fault, passes through the hollow separating Colonsay and the western peninsula of Islay from the rest of the archipelago.

2. The dolomitic 'Fucoid Beds' of Wilkinson and Peach are not the highest geological subdivision of the district, either stratigraphically or structurally. They are earlier than, and structurally they underlie, the greater part of the Islay Quartzite, as well as the whole of the Port Ellen Phyllites and Easdale Slates.

3. In conformity with the previous paragraphs, several correlations must now be abandoned. Thus the Scarba Conglomerate is not the equivalent of the Portaskaig Conglomerate, but is of considerably later date.

4. Small-scale isoclinal folding is of less significance in the greater part of the district than has sometimes been thought. The main feature of the tectonics of Eastern Islay is a comparatively simple isoclinal anticline overthrown towards the north-west upon the Loch Skerrols Thrust. The thrust itself has been well described by Dr. Peach and Mr. Wilkinson.

5. Finally, grounds are given for believing that an accurate knowledge of the structure and rock-concession of Islay is of crucial importance in determining the tectonic plan of the West Highlands generally.

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3. *January* 19, 1916.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communication was read:—

"The Physical Geography of Bournemouth." By Henry Bury, M.A., F.L.S., F.G.S.

The curves of the plateaux in the Hampshire basin (including that of Bournemouth) show a marked relation to the main river-valleys, indicating that the latter were already in existence (though probably much less deep than now) before the plateau-gravel was deposited. On the other hand, the fact that this gravel everywhere covers the main watersheds is inconsistent with the theory of deposition on simple river-terraces, and points to widespread floods and the formation of gravel-sheets at one or more periods. Palæoliths are most frequent at low levels (below 140 feet O.D.), but occur up to 350 feet O.D., where their presence must be due either (1) to a vast accumulation of gravel in Chellean times, or (2) to channelling at later dates. Both hypotheses present difficulties.

The Chines along the coast of Bournemouth Bay did not originate at the cliff-edge and grow inland, as generally stated, but are the over-deepened bottoms of older and longer valleys. A similar double structure is seen in the Chines of the south-western corner of the Isle of Wight, where it is due to the destruction of part of the valley of the Yar by the sea since the deposition of the valley gravel; and it is suggested that the Bournemouth Chines are due to the breach of the Solent River by the sea at the same late period. The 140 ft. bluff, running all across Hampshire to the sea-cliff at Goodwood, is comparable with the 100 ft. terrace of the Thames, and was probably formed in an estuary in pre-Chellean times.

The rate of recession of the cliff in the western part of Bournemouth Bay is estimated at about 1 foot per annum. It may be more in the eastern part, but the estimate of 3 yards per annum near Christchurch, made in the *Natural History of Bournemouth*, is probably much too high; and the reasons given in that volume for local variations in rate cannot be accepted.

The angle of the cliffs is said to have become steeper of late years; but this is not true of the western part of the bay, and it is desirable that the observations on which the belief rests should be published.

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4. *February* 2, 1916.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

A lecture was delivered by Richard Dixon Oldham, F.R.S., on the Support of the Himalaya.

He said that it was known that the major prominences of the Earth's surface are in some way compensated by a defect of density underlying them, with the result that they do not exert the attractive force, either in a vertical or in a horizontal direction, which should result from their mass. A study of the distribution of this compensation shows that there is a general balance between it and the topography, such that the weight of any vertical column through the crust of the earth is, on the average, constant, whatever may be the elevation of the surface. To this condition the term isostasy has been applied, which does not merely denote a static condition, but implies a power of adjustment of the compensation to the variation in load produced by surface denudation and transport.

The explanations that have been proposed of the existence of compensation fall into two classes. One supposes the relief of the surface to be due to an alteration in the volume of the underlying rock, and may be regarded as hypotheses of tumefaction. They involve no addition of matter to the crust under a mountain range, and do not provide, either for any departure from a balance between topography and compensation, or for a restoration of the balance when disturbed by denudation. The other group of hypotheses attributes the origin of the range to a compression of the crust, the injection of molten matter, or the 'undertow' of the lower part of the crust. To provide for compensation any hypothesis of this class will require a downward protuberance of the nether surface of the crust, causing a displacement of denser by lighter material, as also an

effect of buoyancy owing to this difference of density: this group of hypotheses, therefore, may be regarded as one of support by flotation. They involve a migration of matter from outside to beneath the range, they allow of a considerable local departure from exact balance between load and support (or topography and compensation), so long as the defect in one tract is balanced by an excess in an adjoining one, and they provide for an adjustment of any disturbance of this balance.

The geodetic observations in the Himalayas show that there is a defect of compensation in the outer hills, which increases in amount until at about 50 miles from the edge of the hills it reaches an equivalent to an overload of about 2,000 feet of rock. In the interior of the Himalayas the only observation yet published shows that at about 140 miles from the edge of the hills this overload has disappeared, and compensation is in excess. The variation in the balance between topography and compensation points to one of the second group of hypotheses, to a support of the range by flotation, and to the conclusion that the growth of the support has been more rapid than that of the range. The primary problem then becomes, not as to how the Himalayas are supported at their actual height, but why they are not even loftier; in other words, the problem is carried one stage farther back, from the origin of the range to the origin of its 'root'.

This result of the examination of the geodetic data simplifies the explanation of some difficult geological questions. It affords an easy explanation of the indications which are found in the interior of the Himalayas, and of other similar ranges, of simple vertical uplift without disturbance, and also of the manner in which the contorted and faulted strata, the disturbance of which must have taken place under the pressure of some thousands of feet of rock, have been brought up to a level where they are exposed to denudation and their structure revealed; but it brings us very little nearer to an explanation of the ultimate origin of the range. It is a distinct step forward in illustration of the mechanism of the production of mountain ranges of the type of the Himalayas and the Alps, but we are as far as ever from an understanding of the power by which this mechanism is driven.

ANNIVERSARY MEETING.

5. *February* 18, 1916.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following Awards of Medals and Funds have been made:—

The Wollaston Medal is awarded to Dr. Alexander Petrovich Karpinsky, in recognition of his researches concerning the Mineral Structure of the Earth, especially in connexion with the Geology and Palæontology of Russia.

The Murchison Medal, together with a sum of ten guineas from the Murchison Geological Fund, is awarded to Dr. Robert Kidston, in recognition of his valuable contributions to Geological Science,

especially in connexion with the Flora and Stratigraphy of the Carboniferous Rocks.

The Lyell Medal, together with a sum of twenty-five pounds, is awarded to Dr. Charles William Andrews, as an acknowledgment of the value of his researches in Vertebrate Palæontology.

The Balance of the Proceeds of the Wollaston Donation Fund is awarded to Mr. William Bourke Wright, in recognition of his contributions to Quaternary Geology.

The Balance of the Proceeds of the Murchison Geological Fund is awarded to Mr. George Walter Tyrrell, in acknowledgment of his contributions to petrography, especially in connexion with Igneous Rocks in Scotland.

A moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. Martin A. C. Hinton, in recognition of his researches on the British Pleistocene Mammalia.

A second moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. Alfred Santer Kennard, in recognition of his work on the Pleistocene Deposits of the South of England, and on their Molluscan Fauna.

The thirteenth Award from the Daniel Pidgeon Trust Fund was made on March 24, 1915, to Edward Talbot Paris, B.Sc., who proposed to continue his researches on the Lamellibranchia of the Rhætic, Lias, and Lower Oolites of England.

II.—Edinburgh Geological Society.

1. *December* 15, 1915.—Dr. Robert Campbell, President, in the Chair.

1. "Professor George Sinclair's 'Short History of Coal', published in Edinburgh 1672." By D. Tait.

In this paper Mr. Tait brought before the notice of the Society a work called *The Hydrostaticks*, written by George Sinclair, Professor of Philosophy and Mathematics in the University of Glasgow, who is best known as the author of *Satan's Invisible World Discovered*, a book on ghosts and witches. A section of *The Hydrostaticks* is entitled "A Short History of Coal". In it is given the first account of the Midlothian coalfield. The outcrop of the 'great' seam of coal is traced round the basin and also in the neighbourhood of Prestonpans and Tranet in a remarkably accurate manner. He notes that whin dykes often render coal-seams with which they come into contact as if they had been burnt, and records many other interesting geological facts in the neighbourhood.

2. "A Diatomaceous Deposit at the East End of Loch Leven, Fifeshire." By J. Duncan. With Note on the Diatomaceæ by George West.

This deposit forms part of the alluvial flat at the east end of Loch Leven. It was first observed in a trench cut for a water-pipe track near the Old Gullet Bridge, which crosses the former course of the River Leven near Lochend farm-house, and afterwards traced eastwards to East Bowhouse, a distance of about two miles. The greatest thickness of Diatomite met with in the series of pits made

was 1 foot. It is not continuous over the area, but occurs in patches on slightly raised ground. Some parts of this deposit may be of commercial value for use as an abrasive.

A microscopic examination of the deposit was made by Mr. G. West, of the Botanical Department, University College, Dundee, who makes out a list of thirteen genera of diatoms.

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2. *January* 19, 1916.—Dr. Robert Campbell, President, in the Chair.

1. "Notes on the Former Courses of the River Devon." A suggested Evolution for part of the River System of Fife and Kinross. (With lantern illustrations.) By J. E. Wynfield Rhodes, B.Sc., M.I.M.E.

In this paper an attempt is made to trace out the evolution of the valleys of the Rivers Devon, Eden, Leven, and their tributaries. Starting from the assumption that the original or consequent drainage was E.S.E., an assumption justified by the study of other districts on our eastern seaboard and in entire harmony with the evidence obtainable locally, the positions of two of the original streams A and B are postulated. This constitutes the first stage in the evolution, and the gradual development of our present river system in this area is shown to occur in four subsequent stages. The course of stream A is marked by the following valleys: Glen Lednock, Glen Eagles, Glen Devon, the Gairney Water Valley, Blairadam windgap, and the Chapel Burn. Stream B was parallel to it, and its site is marked by the S. Queich, Loch Leven, and the Lochy Burn. Stream A is beheaded at Muthil, thus producing the obsequent Glen Eagles Valley, and near Cardenden by the River Ore, a tributary of stream B. Subsequently a stream cutting back along the Ochil fault beheads stream A at the Crook of Devon and the River Devon is produced. In the next stage the strike stream Eden beheads both A and B and develops the Plain of Kinross; Blairadam and Ballingry windgaps are thus produced. Finally, in the Glacial period, Loch Leven is produced by a drift dam at Mawcarse, the waters of the lake escaping by the Leven Valley.

2. "Veining and Metasomatism in Basalt at Upper Whitfield, near Macbiehill." (With lantern illustrations.) By T. Cuthbert Day, F.C.S.

The author recognizes the great variety of ways in which veining may occur in igneous or in sedimentary rocks, and does not pretend to put forward a theory of uniform application. He merely describes a particular case, and seeks to maintain that the veining in the basalt at Upper Whitfield has not been caused by infiltration of mineral matter into ready formed fissures or dislocations in the basalt, but by a methodical replacement of the basalt along the layers of exfoliation, the basalt itself being removed piecemeal and its place taken by veining material. An example of what might be considered as metasomatism in the same basalt is also described, the prime cause of the alteration being due to some defect in the part of the basalt at the time of intrusion which rendered it liable to attack by mineral solutions. An attempt is made to explain the order of the changes

in the basalt, the first being a large replacement of the basalt by a deposit of siliceous material, which was itself subsequently, in a considerable measure, removed and replaced by a deposit of calcite.

III.—Geological Society of Glasgow.

At a meeting of the Geological Society of Glasgow, held on January 13, 1916, Mr. Alex. Scott, M.A., B.Sc., read a paper on "The Physiography of Glen Lednock". He pointed out the place of Glen Lednock in the general valley system of the Highlands, and said that the glen now contained a number of dry river channels, only one of which was now in use. It was pointed out that the fragments, now isolated, could be pieced together with fair certainty. The position of each of these fragments was described, and the reasons for their formation and successive abandonment discussed. Most of these channels are fairly shallow and open, but at the Deil's Cauldron the stream has cut a deep gorge, and this has been done by pothole action, as very fine examples of these are to be seen in the walls. In this case the dip of the beds seems to have played an important part in determining the position of the channel, but in other cases the junction between hard and soft rocks seems to have been the controlling factor.—Professor Gregory complimented the author on his paper, and agreed with him that Glen Lednock was of great antiquity and probably pre-Glacial. He also pointed out that it was only by the study of these river valleys that it was possible to elucidate the history of Scotland during the long period between Tertiary and post-Glacial times, as there were no deposits of that age in Scotland to contain a record. The study of this and similar glens also threw light on the question of whether movement was constantly proceeding on the line of the Highland Boundary Fault. The existence of a sudden drop in the beds of such glens points to there having been a sudden uplift of the country north of the fault in comparatively recent times.—In reply the author stated that the apparent rejuvenation of these glens does point to an uplift, but it may be due to another cause. In Glen Turret, however, the burn is cutting Old Red Sandstone on both sides of the fault, and therefore the pronounced fall in that glen supports Professor Gregory's suggestion. He agreed with Mr. Macnair that dykes do have some connexion with the direction of the gorges.

"On an Ancient Shore-line." By M. Macgregor, B.Sc., H.M. Geological Survey. The Helmsdale Boulder Bed, with which the paper deals, dated from late Jurassic time, and consisted of a tumultuous accumulation of blocks, the majority angular, embedded in shales, sandstones, and shelly limestones which were contorted at the points of contact. The boulders had been determined as all of Middle Old Red Sandstone age, with a regular ascent in the series from north to south. The age of the bed had been determined by means of its plants as Kimmeridgian, and by means of a coral as Portlandian. The author described the structure of the district and summarized the views on the origin of the boulder bed of various authorities who had examined it. These opinions were shown to be untenable from

one circumstance or another, with the exception of that briefly stated by Woodward in 1910; he suggested that the boulder bed was an accumulation of debris dropped from sea-cliffs into deep water. No theory of water transport could account for the presence of a boulder 190 × 50 × 30 feet, consisting of frequent alternations of fissile sandstone, etc., and there is no evidence of glacial action. The author suggested that the boulder mentioned was just a sea-stack which had capsized, and showed a series of photographs of the boulder bed and of the scenery of the present Old Red Sandstone cliffs of the Sutherland coast, pointing out how the conditions of these would give rise to a deposit possessing exactly the characters of the boulder bed.—Professor Gregory congratulated Mr. Macgregor on having solved a problem that had baffled so many authorities. The solution showed that Old Red Sandstone strata must have covered that district as recently as late Jurassic times.

IV.—Liverpool Geological Society.

February 8, 1916.—J. H. Milton, Esq., F.G.S., F.L.S., President, in the Chair.

The following paper was read:—

"The Origin of the Trias: a restatement of the problem." By H. W. Greenwood.

The author reviewed and criticized previous theories in the light of recent work, and considered them to be based largely on a misinterpretation of facts, conditions having been assumed which have not yet been proved to have existed. The principal conclusions at which he had arrived were: (1) That no true line of demarcation existed in Great Britain between the Permian and Triassic systems, which must be dealt with as a whole. (2) That present-day topography was a partial restoration of pre-Triassic topography. (3) That the material of the various British Trias deposits had been derived from different sources, and that no general theory of river or desert origin was applicable to all or any of the deposits. (4) That the evidence pointed to arid climatic conditions existing between the close of the Carboniferous and beginning of the Jurassic periods. (5) That the Trias deposits of the Liverpool district, Cheshire, and the Vale of Clwyd were all derived from the same source, which lay to the west and south-west, and that the Bunter and Keuper divisions were unconformable. The high content of calcium carbonate which chemical analyses had revealed was an original character, and due to the denudation of Carboniferous Limestone and Coal-measures.

V.—Mineralogical Society.

January 18, 1916.—W. Barlow, Esq., F.R.S., President, in the Chair.

Professor G. Cesàro: A simple Demonstration of the Law of Miller. In any spherical triangle the arc x joining the apex C to a pole dividing the base c into segments a and β is given by the equation $\cos x \cos c = \cos a \sin \beta + \cos b \sin a$. Taking the apex as the pole

of one of the axes and the base as the zone containing the four poles, the usual anharmonic ratio is obtained. — Dr. G. T. Prior: The Meteorite of Daniels Kuil. The meteorite consists of nickeliferous iron in large amounts, troilite, oldhamite, felspar, and enstatite, free from iron, and thus belongs to the exceptional Hvittis and Pillistfer group of chrondritic stones, to which also must be added the Khairpur meteorite, which contains notable amounts of oldhamite.—Dr. G. T. Prior: On the Relationship of Meteorites. Meteorites may be arranged by their chemical and mineral composition into the following six groups—(1) Bustee and Hvittis group, (2) Siderolites, (3) Cronstad group, consisting of chondrites containing over 10 per cent of nickeliferous iron, (4) Baroti group, consisting of chondrites containing less than 10 per cent of nickeliferous iron, (5) Chladnite group, including Chladnites, Angrites, Chassignites, Amphoterites, some Rodites, and probably some Chondrites containing little nickeliferous iron, (6) Eucrites, Nakhlites, Shergottites, Howardites, and some Rodites. It is suggested that from the first group the remaining stones have been derived by the interaction between oxidizing nickeliferous iron and enstatite, with consequent production of ferriferous olivine and bronzite, the formation of chondrules, and enrichment in nickel of the residual iron. The nickeliferous iron of the first three groups corresponds to the more common meteoric irons, such as the octahedrites and hexahedrites, containing less than 10 per cent of nickel, and that of the last three to nickel-rich Ataxites, containing more than 10 per cent of nickel. The groups (2)–(6) contain progressively diminishing amounts of nickeliferous iron, which is increasingly rich in nickel, and have increasing amounts of ferrous oxide in the ferro-magnesium silicates, in which the ratio of magnesium to iron atoms approximates in the case of group (2) to 7, of group (3) to 5, of group (4) to $3\frac{1}{2}$, of group (5) to 2, and of the last group to 1 or less.—Dr. J. W. Evans: The isolation of the directions-image of a section of a mineral in a rock-slice. In some optical investigations, e.g. the observation of the interference-figures of minerals in thin sections under the microscope, the determination of the angle of total reflection, and the measurement of crystal angles, the image studied is not that of the object, but is one in which every part corresponds to a direction in which light is transmitted, or in other words it is a directions-image. To prevent the effects of closely adjoining objects being blended all light except that traversing the object under investigation must be screened by a diaphragm placed near it or in a position conjugate with it. In an ordinary petrological microscope this may often be conveniently effected by placing the diaphragm below the condenser, so that the image of the aperture is seen in focus simultaneously with that of the object. The best results are, however, obtained when the diaphragm is placed in the focus of the eye-piece, and, after it has been adjusted, the Becke lens placed above it. The same method may be employed with advantage in the other observations referred to, the instrument employed being constructed primarily as a microscope, and converted into a telescope by the addition of a lens, instead of vice versa as is the usual procedure.—Dr. J. W. Evans: A new method of determining the angular direction

represented by a point in the directions-image. A circular plate is ruled with concentric circles at distances from the centre equal to $r \tan \theta$, where θ stands for different angles at intervals of 5° up to the full aperture of the objective and r as a constant length, say 50 mm., and with radiating lines 5° apart; it may be placed on supports which fix its position above the stage. When the microscope is adjusted for observations of the directions-image of a mineral, the point, the angular position of which is to be determined, is identified by the end of an adjustable pointer, which is placed so as to be seen in focus. The microscope is then focussed up until the objective is accurately at a distance r from the plate, which is now placed in position and is clearly seen. The angular position required is then shown by the position of the end of the pointer relatively to the scale of the plate.—L. J. Spencer: A new (seventh) List of Mineral Names.

CORRESPONDENCE.

ON GLACIER LAKE CHANNELS.

Sir,—As I have stated my case at some length in regard to the 'overflow channel' valleys, and as Professor Kendall and Mr. B. Smith in their courteous criticisms restrict themselves mainly to points of detail, most of which had been noted in my pamphlet, while omitting to discuss the fundamental difficulties to which I called special attention, I must not weary your readers with more than a few words. Each of them, I may remark, has confined himself, perhaps wisely, to the district which he has made his own. Hence they have not dealt with the Ringstead Down 'railway trench' (which is perfect from its head to its end, besides having a lateral tributary of more normal form), or with the ancient and more modified trenches near Hawes Junction and in the Dufton Pike district, or with those in the Cleveland and Black Combe districts, which are occasionally perfect or are suggestive of decapitation. Nor have they met my objection that the shape of the trenches is not such as should be the result of an overflow from an ice-dammed lake (see my pamphlet, pp. 7 and 8), for what Professor Kendall does say on this subject seems to me hardly to meet my objection. He and Mr. B. Smith lay much stress on the fact that spurs are severed by channels transverse to the valleys by which those spurs are defined, no doubt a thing not easily explained, but they apparently forget that similar and similarly situated trench valleys occur in the Dufton Pike district and in that to the south of Cader Idris, where the lake overflow hypothesis seems to me an impossible explanation. Nor, so far as I can see, does the "marginal drainage of an ice-sheet" really help us. Of course that would erode, but so far as my experience goes (and it is a fairly large one) it would find the cutting of a flat-bottomed trench very difficult and that of an 'in-and-out' impossible. Much of what Von Engeln says of marginal drainage is familiar to me, and the channels cut by it are not 'railway trenches' but nearer to gorges. Also, Mr. B. Smith forgets to mention that the granite

in which channels were quickly cut was "very much shattered by close jointing". It is no doubt a little remarkable that, supposing these trench valleys to be, geologically speaking, rather ancient, their sides are not more furrowed; but water-worn valleys in the Bunter pebble-beds, the Neocomian Sands, and the Chalk downs of Southern England often have their sides unfurrowed, and cliffs of limestone, on a comparatively small scale in England and on a gigantic one in the Alps, are frequently smooth for considerable distances, showing that atmospheric denudation has about kept pace with that from streamlets. The same sometimes holds good with sandstone and granite.

Finally, they forget that the invasion of the larger part of England by great ice-sheets is just as much an hypothesis as that of submergence, and cannot be regarded as an axiom until the difficulties to which I have repeatedly referred have been fairly met (instead of being ignored) and removed. I may add that I cannot accept as moraines (with which I ought to be familiar) several of those to which some geologists give that name. But my pamphlet will fulfil its purpose if it leads to a more careful study of the whole question, instead of such reasoning as this: "Here is a peculiar valley: how can we associate it with terrestrial ice-sheets?" To me the safer method seems this: "Here are certain physical facts: what inference do they suggest?" I do my best to keep "my mind from being set awhirl" when it arrives at a conclusion which is contrary either to a popular opinion or to what I was taught in my younger days.

T. G. Bonney.

A METHOD OF HARDENING FRIABLE FOSSIL WOOD FOR SECTION-CUTTING.

Sir,—While collecting from the Lower Gault in the neighbourhood of Farnham, Surrey, I often found fragments of what was evidently driftwood lying amongst the shells. It was extremely friable; in fact, when dry, it was, as a rule, impossible to touch it or even blow upon it without causing it to fall away in powder; and to obtain a section from such material seemed well-nigh impossible.

When treated in the usual way with silica solution the wood did not appear to be permeated, but merely to be—in the mechanic's term —'case-hardened,' that is, to have formed on the surface a very thin crust of hardened substance, rendering the specimen useless for section-cutting.

It occurred to me, however, that a better result might be obtained by *forcing* the silica solution into the wood, on the same principle as that by which railway-sleepers are impregnated with creosote under pressure. An ordinary model steam-engine boiler was, accordingly, adapted for the purpose. First the filling hole was enlarged enough to admit a piece of the wood, and a certain fitting, stocked by all model makers, added. This consists of an ordinary bicycle tyre valve threaded on the outside to screw into the boiler. This attached, sufficient silica solution (undiluted) was poured in to cover the wood, the filler-cap screwed on, and the boiler pumped up with an ordinary cycle-pump. The pressure was raised to 30 lb. per square inch,

and the whole left for five days, except that it was occasionally pumped up to maintain the pressure, which dropped rather rapidly; in fact, on several occasions, namely at night, there can have been no pressure at all for some hours, as it was always necessary to have recourse to the bicycle pump in the morning. On being taken out after five days, the wood was found to be much harder, or rather, it was *tough*—I could make no impression on the wood by scratching with my finger-nail, but it had a hard *leathery* feeling when scratched. It was now allowed to dry by simple exposure to the air in my workshop, and in six days more appeared to be dry.

I should add that before hardening it as above described I had managed to cut one end of the wood flat, across the grain. The wood being dry, I now attempted to polish it by simple rubbing against a soft cloth, and obtained a fair polish, but, not having the necessary apparatus or skill to cut a section, I gave the specimen to the British Museum of Natural History, where it now is. Hoping that this description may be of use to others.

CHRISTIAN TINNE.

THE CHINE, WRECCLESHAM, FARNHAM.
January 6, 1916.

WILLIAM SMITH'S MAPS.

SIR,—I am preparing a monograph on Smith's maps, etc., for the Yorkshire Geological Society, and am anxious to see a "Reduction of Smith's large Geological Map of England and Wales intended as an elementary map for those commencing the study of Geology, 1819", referred to in Phillips's *Memoirs of Smith*.

I find that Smith's large maps of 1815 often bear a signature and a number, such as "No. 66" or "a 33". If any readers of the GEOLOGICAL MAGAZINE possess copies of this large map, perhaps they would kindly inform me what number the map bears. It occurs under the "Section of Strata", which appears on the map to the east of the Humber estuary.

T. SHEPPARD.

THE MUSEUMS, HULL.
January 25, 1916.

OBITUARY.

HERMANN GRAF ZU SOLMS-LAUBACH,

SC.D., FOR. M. ROY. SOC., FOR. M. LINN. SOC., FOR. M. GEOL. SOC.

BORN DECEMBER 23, 1842. DIED NOVEMBER 24, 1915.

COUNT SOLMS-LAUBACH was well known amongst men of science as a most distinguished botanist. His death was communicated to this country by Professor A. G. Nathorst, the Swedish Palæontologist of Stockholm.

Count Solms was born in 1842, and was in his 73rd year. He devoted his life wholly to science. He was Professor of Botany at Göttingen and afterwards at Strasburg, from which he retired a few years since.

His work extended to every department of botany. Perhaps the most important of all was that on fossil botany. He was an intimate friend of the late Professor Williamson. His *Palæophytologie*, published in 1887, was translated for the Oxford Press in 1892. In it the author impresses on botanists the value and significance of the geological record as affecting plants.

Of special importance may be mentioned his paper on *Bennettites Gibsonianus*, a fossil Cycad from the Isle of Wight; on the Cycadofilices, *Protopitys*, Medullosa, etc.; on Devonian and Lower Carboniferous Plants; and on *Psaronius*.

He was elected a Foreign Member of the Linnean Society in 1887, of the Royal Society in 1902, and of the Geological Society in 1906. He received the Gold Medal of the Linnean Society in 1911, and was made a Sc.D. of the University of Cambridge at the Darwin celebration in 1909.

[D. H. S. From *Nature*, January 13, 1916.]

THOMAS SERGEANT HALL, M.A., D.Sc.

BORN 1858. DIED DECEMBER 21, 1915.

A SERIOUS gap has been made in the ranks of Australian geologists by the deeply regretted death of Dr. Hall, on December, 21, 1915, at the comparatively early age of 57.

Dr. Hall occupied the post of Lecturer in Biology at the Melbourne University, where he was greatly esteemed as a teacher. He was perhaps better known abroad as an ardent geological worker amongst the Victorian graptolitic and Tertiary rocks. In 1899 he contributed an important paper to this Magazine on "The Graptolite Rocks of Victoria, Australia". In recognition of his work on the distribution of Australian graptolites, embodied in many important contributions to various journals, he was made the recipient of the Murchison Fund of the Geological Society of London in 1901. The subdivisions of the Victorian Ordovician rocks were suggested and worked out in detail by Dr. Hall. He had also devoted much time to the study of the interesting and somewhat complex series of Tertiary fossiliferous strata of Victoria, generally in conjunction with Dr. Pritchard; and these authors originated the useful local terminology now usually applied to the subdivision of these rocks. In all his undertakings Dr. Hall was very thorough, and his intimate knowledge of the biological side of the science added to the value of his palæontological work. Always ready to help his confrères, especially in the domain of scientific literature, he will by them be greatly missed. His book on *Victorian Hill and Dale* has done much to foster a popular taste for outdoor geology, and his series of chatty articles in the *Australasian* on current scientific topics under the pen-name of Physicus were widely read. In the cause of maintaining a high standard for our Victorian scientific libraries, and especially that of the Royal Society of Victoria, of which he was the Hon. Secretary for fifteen years and President in 1914–15, Dr. Hall did significant service, which alone would justify his high reputation as a devoted scientific worker.

F. C.